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Final Technical Report
July 1970

AUTOMATED TECHNICAL CONTROL

Volume I - System and Facility Investigations and Considerations

Philco-Ford Corporation

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Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

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FOREWORD

This final report was prepared by members of the technical staff of Philco-Ford Corporation, 3900 Welsh Road, Willow Grove, Pa 19090 under Contract F30602-69-C-0116, Project 7048, Task 704801. Mr. R. R. Reaser served as Project Manager and Mr. D. Elsas served as Technical Manager for the program. Major technical contributors were as follows: Messrs. R. Dunbar, J. Eyrich, J. Fisher, F. Greim, V. Huber, E. Lounsberry, J. Malcomson, M. Marhefka, G. Nickett, H. Okamoto, N. Sher and A. Shultz. Numerous other individuals offered valuable advice, comments and criticisms. The Rome Air Development Center project engineers were Messrs. John D. Kelly, James L. Davis and Anthony S. Szalkowski (EMCAS).

This technical report is based upon the results of the study and investigation performed under Exhibit Line Item A001. The study and investigation effort was accomplished during the period of 18 February 1969 to 18 December 1969.

The distribution of this report is restricted under the U. S. Mutual Security Acts of 1949.

This technical report has been reviewed and is approved.

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ABSTRACT

This report describes a study performed to determine cost-effective and technically effective means and methods of automating the functions of DCS technical control facilities. In determining the degree of automation that could be applied to the various functions, the DCS environment, telecommunications systems and equipment, and technical control operating activities were considered. The requirements for Automated Tech Control (ATEC) facilities and an ATEC augmented DCS were also determined.

As a result of this study, it was concluded that circuit status monitoring provides the most benefit in fault detection and localization. Automation of this and other ATEC functions is recommended through use of a processor, which would also provide controlled data storage and display information to manned consoles. In addition, the processor would correlate status monitoring information from equipment, links, and circuits to provide performance assessment and trend analysis. Other recommended functions to be automated include: report generation; remote site status monitoring; and group patch, circuit patch and digital patch switching. The cost of switch matrices precludes implementation of all circuits, and switching is therefore recommended only on a limited basis, such as for high priority digital and audio circuits and selected carrier multiplex groups.

The recommended ATEC configuration provides for Status Monitoring, Quality Control and Central Control consoles to be operated by tech control personnel. Patch bays with sealed normal-through contacts are recommended with connection capability to test and monitor buses which will be accessed by the console operators. An integrated orderwire and intercom capability is recommended for coordination and control between elements of the ATEC facility; with other ATEC and manual technical control facilities; and with subordinate patch and test facilities, users and communications suppliers.

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ABBREVIATIONS

ACK	Acknowledge
ACOC	Area Communications Operation Center
A/D	Analog to Digital
AF	Audio Frequency
AFB	Air Force Base
AFC	Automatic Frequency Control
AFCS	Air Force Communications Service
AFSK	Audio Frequency Shift Keying
AGC	Automatic Gain Control
ALC	Automatic Level Control
AM	Amplitude Modulation
AME	Amplitude Modulation Equivalent
ASCII	American Std. Code for Info Interchange
ATEC	Automated Technical Control
ATECF	ATEC Facility
AUTODIN	Automatic Digital Network
AUTOVON	Automatic Voice Network
BB	Baseband
BER	Bit Error Rate
BP	Bandpass
b/s	Bits/Second
BSM	Basic Switching Module
BW	Bandwidth
CCO	Circuit Control Office
CDMA	Code Division Multiplex Access
CEI	Contract End Item
CEO	Circuit Engineering Orders
C/kT	Carrier-to-noise Power Density
CLR	Circuit Layout Records
CMO	Communication Management Office
C/N	Carrier-to-noise
CONUS	Continental United States
CRT	Cathode Ray Tube
CSP	Capacity - Success Product

ABBREVIATIONS (Continued)

dB	Decibel
dBm	Decibel Referenced to 1 Milliwatt
dBm0	Decibel Level Referenced to Zero Test Tone
dBr	Decibel to a Specified Reference
DC	Direct Current
DCA	Defense Communications Agency
DCAC	DCA Center
DCAOC	DCA Operations Center
DCS	Defense Communications System
DOCC	DCA Operations Control Complex
DSCS	Defense Satellite Communications System
DOD	Department of Defense
ED	Error Detection
EDC	Error Detection and Correction
EDD	Envelope Delay Distortion
EIA	Electronic Industries Association
EOM	End of Message
EOT	End of Transmission
ESC	Echo Suppressor Control
FCO	Facility Control Office
FDM	Frequency Division Multiplex
FDMA	Frequency Division Multiple Access
FDX	Full Duplex
FF	Flip Flop
FFP	Fixed Function Program
FM	Frequency Modulation
FOT	Frequency of Optimum Transmission
FOX	Teletypewriter Test Message
FSK	Frequency Shift Keying
FSVM	Frequency Selective Voltmeter
FTR	Failure Report
G/A	Ground-to-air
GHz	Gigahertz
GMT	Greenwich Mean Time
GPS	Groups

ABBREVIATIONS (Continued)

HDX	Half Duplex
HF	High Frequency
HQ	Headquarters
HP	High Power
HPA	High Power Amplifier
Hz	Hertz
IC	Integrated Circuits
IDCSP	Initial Defense Communications Satellite Project
IF	Intermediate Frequency
ICO	Intermediate Control Office
I/O	Input Output
IOR	Initial Outage Report
IPA	Intermediate Power Amplifier
ISB	Independent Sideband
ITA	International Telegraph Alphabet
JCS	Joint Coverage Subcommittee
kb/s	Kilo bits second
KHz	Kilo Hertz
KSR	Keyboard Send-Receive
KW	Kilo Watts
LNA	Low Noise Amplifier
LOS	Line-of-Sight
LOW	Link Orderwire
LP	Low Pass
LPA	Low Power Amplifier
LUF	Lowest Usable Frequency
m	meter
mi	Mile
MHz	Mega Hertz
mm	millimeter
MP	Message Processor
MRC	Modulation Rate Converter
MUF	Maximum Useable Frequency
MUX	Multiplex
MW	Microwave
MWO	Modification Work Order

ABBREVIATIONS (Continued)

NACK	Negative Acknowledge
NAVAID	Navigational Aid
NCMO	NAVAIDS Communications Management Office
NCS	National Communications System
NPR	Noise-to-Power Ratio
OCM	Operational Coordination Manager
ODM	Operational Direction Manager
OEM	Original Equipment Manufacturers
OL/NT	Open Line or No Transmission
O&M	Operation & Maintenance
OER	Operational Evaluation Reports
OW	Orderwire
PA	Power Amplifier
PAR	Peak to Average Ratio
PABX	Private Automatic Branch Exchange
PBX	Private Branch Exchange
PCM	Pulse Code Modulation
PEP	Peak Envelope Power
PNG	Pilot Noise Gate
P-P	Point-to-point
P-P	peak-to-peak
PPM	Pulse Position Modulation
PSK	Phase Shift Keying
P&T	Patch and Test
PTF	Patch and Test Facility
PV	Path Verification
PW	Printed Wiring
PWM	Pulse Width Modulation
QSY	Frequency Change
R&DC	Research and Development Command
RCOC	Regional Communications Operations Center
RDT&E	Research, Development, Test & Evaluation
RF	Radio Frequency

ABBREVIATIONS (Continued)

RFO	Reason for Outage
RMS	Root Mean Square
RO	Receive Only
RPA	Receiver Performance Assessor
RR	Restoral Report
RSL	Receive Signal Level
RTTY	Radio Teletypewriter
SC	Service Channel
SCCO	Special Circuit Control Office
sec	Second
SET	Satellite Earth Terminal
SF	Single Frequency
SGPS	Supergroups
SHF	Superhigh Frequency
SID	Site Identifier
S/N	Signal-to-noise ratio
SO	Send Only
SOM	Start of Message
SOP	Standard Operating Procedures
S/S	Shore-to-ship
SS	Spread Spectrum
SCCO	Special Circuit Control Office
SSB	Single Sideband
T&A	Test and Acceptance
TC	Technical Control
TCF	Technical Control Facility
TCTO	Time Compliance Technical Order
TDM	Time Division Multiplex
TDMA	Time Division Multiplex Access
TPA	Transmitter Performance Assessor
TTY	Teletypewriter
TWT	Traveling Wave Tube
TX	Transmitter
UHF	Ultra High Frequency
UPS	Uninterrupted Power System

ABBREVIATIONS (Continued)

VF	Voice Frequency
VFCT	Voice Variable Frequency Carrier Telegraph
VFO	Variable Frequency Oscillator
VHF	Very High Frequency
VLF	Very Low Frequency
VSWR	Voltage Standing Wave Ratio
W	Watt
WPM	Words Per Minute
WWVB	National Bureau of Standards Radio Station, Ft. Collins Colorado VLF Station, 60 kHz Standard Frequency and Time Signal
WWVH	Maui, Hawaii - National Bureau of Standards Radio Station - Standard Frequency and Time Signal

SECTION I

INTRODUCTION

1. STUDY REQUIREMENTS

The primary contractual requirements of the Automated Technical Control (ATEC) Study Program which were pertinent to the generation of this technical report were as follows:

"Translate the ATEC concept and requirements (as specified in AFCS Report 5-OHR-67) into an operational system, including determination of significant measureable system parameters, determination of the specific techniques, equipment (including test and realignment procedures for the equipment) and interface criteria required to implement the system and determination of the need to modify existing technical control operational procedures or establish new procedures to accommodate semi-automated operations."

"It cannot be over emphasized that the main objective of the program is to define an operational system which, by the incorporation of standardization and equipment function modularization techniques, shall be capable of being implemented on a worldwide basis at technical control facilities of varying configurations."

"The scope.....shall include, but not be limited to, the following areas of investigation in order to translate the ATEC concepts and requirements into a system and to define the equipments (hardware and software) and functions required to implement the system."

a. Equipment Status and Monitoring

b. Link Status and Monitoring

c. Circuit Status Monitoring

d. System Performance Status Monitoring

e. Displays

f. Line Conditioning

g. Programming

h. Reports and Special Telemetry for Communications

i. Central Control Position

j. Technical Control Patch Panel

k. Central Station Clock

l. Standardization and Modularization

m. Test Equipment

n. Training

o. General Requirements, including power and space

"Technical reports shall be provided to record the technical efforts and achievements accomplished. . . . ."

The Contract Data Requirements List (CDRL) includes the following items, of which B004 is the above required report, namely, this document. However, the other items are directly related to this report in that they are dependent upon the results contained herein.

- B001 System Performance/Design Requirements General Specification
- B002 Contract End Item Detail Specification (Prime Equipment) Part I
- B003 Contract Status Report
- B004 Technical Report – this document
- B005 Integration Plan
- B006 Reliability Analysis for Exploratory Advanced Development Models
- B007 Maintainability Analysis for Experimental Advanced Development Models

2 STUDY OBJECTIVES

Exhibit A of the contract documents stated the following:

"The ultimate objective of this program shall be to establish and demonstrate a system for semiautomating technical control functions associated with complex analog and digital communications systems. This system shall provide the Air Force and the DCS with rapid, precise and documented quality control, analysis, alternate, restoral, circuit conditioning, and other functions demanded by present and future high density communications systems."

"Present technical control capabilities are grossly inadequate to meet the demands for optimum operation and control of both present and future analog and digital communications systems. Due to burdensome techniques and instrumentation for prediction of system failures, corrective actions are not taken until failure occurs or a customer alerts the technical controller to a deteriorating or failure condition."

"This 'move only if forced' type of operation results from facility limitations, in that existing facilities have evolved from assets furnished under many unrelated programs."

"By contrast, the ATEC concept embraces a failure prediction feature—the firm and continuous proof of performance mode of operation and addresses automation, standardization and (equipment) modularization and a degree of equipment redundancy in such areas as equipment systems performance, status and analysis, line conditioning, dynamic displays, remote patching, report submission and control consoles."

3 STUDY METHODOLOGY AND REPORT ORGANIZATION

The total ATEC study effort, performed under Exhibit Line Item A001 of the ATEC contract was divided into a number of individual study tasks identified in Table 1. Each of these study tasks was investigated in detail by engineering specialists possessing specific knowledge and experience pertinent to the subject of that task. The System Design and Development task group served as the guiding element of all other task group efforts. This group established the point of coordination for each of the other groups and coordinated the efforts of the various groups, thereby ensuring unity of purpose, proper interchange of information, coordination of interfaces, and recognition of the impact of any decision on individual task groups.

The System Design and Development task group first generated a document entitled "Technical Control Functional Definition." This document functionally defined each technical control task and described the interrelationship and interdependency of the various tasks. This functional definition then provided the basis from which automation of technical control functions could be investigated. A second initial document generated by this group was entitled "Contract Definition Scope of Work." This document delineated the specific efforts to be performed by each of the individual task groups and assured that no contract requirements would be omitted. The Systems Design and Development group also reviewed and analyzed DCA documents 310-[illegible] through -3 and DCAC 310-[illegible] in order to determine exactly what equipments and configurations, as well as quantities, existed at various types of stations within the DCS. This information was distributed to all other study task groups as guidance relative to determination of design approaches, modularity, expansion requirements, and cost-effectiveness. Also, the systems group initiated

Table I ATEC Study Tasks

STUDY TASK	APPLICABLE SECTION(S) OF THIS REPORT	
	VOLUME I	VOLUME II
System Development and Design	III thru VI	
Link Status and Monitoring		VII
Equipment Status and Monitoring		VIII
Circuit Status Monitoring		IX
System Performance Status Monitoring		X
Central Control		XI
Telemetry Analysis		XII
Technical Control Automated Patching		XIII
Reporting Requirements		XIV
Programming and Processor Hardware		XV
Display and Control Analysis		XVI
Human Factors		XVII
Teletypewriter and Voice Orderwire		XVIII
Line Conditioning		XIX
Central Station Clock		XX
Test Equipment		XXI

a preliminary systems design approach, in consideration of AFCS Report 5-ORR-67, for integration and evaluation of concepts and techniques to be developed by the various task groups. This initial design approach was periodically changed and updated as inputs were received from the various task groups.

The other individual task group efforts essentially began at these starting points, established by the Systems Design and Development group. The individual groups investigated their respective areas intensively, beginning with a more finite determination of task requirements, a review of ATEC objectives, and the establishment of necessary background. Candidate techniques and approaches were developed for consideration. These were evaluated and selected approaches were justified. Sources of required data were optimized with respect to quantity and value. The resulting most technical and cost-effective approaches were provided to the Systems Design and Development task group for integration and coordination with other tasks. The efforts and results of the various individual study task groups are documented in the appropriate sections (Section VII through XXI) which comprise Volume II of this report, as referenced in Table I.

The System Design and Development task group assimilated all of the inputs from the various other task groups. This was a continuous process from the commencement of individual task efforts until completion of these efforts and final generation of the individual task reports mentioned above. Based upon the results and recommendations obtained from these tasks, the optimum system approach was developed. The system requirements were investigated from functional, operational and hardware (and software) aspects. These efforts are documented in Sections III and IV of this report. Considerable attention was also given to the cost-effectiveness aspects of ATEC as documented in Section V. The conclusions and recommendations resulting from the total system design and development study efforts are provided in Section VI. Section II provides a comprehensive summary of the total study efforts and results achieved therein. Sections I through VI of this report comprise Volume I.

Although the efforts and achievements of the individual task groups were continually reviewed and coordinated by the systems group, the conclusions and recommendations reached by the individual tasks are not necessarily consistent with the final system conclusions and recommendations eventually derived by the System Design and Development task. That is, the individual study tasks reached certain recommendations as a result of their individual efforts, and which could not take into full account the results obtained by all other tasks. These conclusions and recommendations are contained in the last paragraphs of each of the individual task reports; namely, Sections VII through XXI of Volume II of this report. However, when the results of all of these individual task efforts were combined and considered relative to the overall ATEC Facility and ATEC System Design and Development, it was determined that certain deviations from, or variations to, these results were required. The rationale and justification for these deviations and variations are contained in Sections III, IV and V of Volume I. The resulting conclusions and recommendations

are those contained in Section VI of Volume I. The important fact to be noted is that Volume I of this report necessarily contains certain apparent inconsistencies and contradictions relative to Volume II, and vice versa. Hence, the considerations and results as contained in Volume I are to be considered primary. Further details, and derivation and justification of these details are the major function of Volume II.

SECTION II

SUMMARY

The objective of the study was to establish a system that verify its feasibility for semiautomating the many functions of Technical Control. Further, the system was to provide for rapid, precise and documented quality monitoring and testing, analysis, reroute, restoral, reporting and other functions associated with providing optimum service through present and future high density communications systems. Among the basic precepts for such a system were:

a. Continuous proof of performance

b. Failure prediction

c. Near-real-time failure detection

d. Multilevel (Green-Amber-Red) status indication

e. Rapid restoral

f. Minimum interruption or degradation of user service

g. Improved accuracy, speed and historical records

h. Reduction in operator and maintenance personnel

i. Semiautomation required in the sense that final decisions and approvals must be operator initiated

The total problem was broken down into a number of individual study tasks to permit intensive investigation of each specific area. The results, as well as the conclusions and recommendations of each of these areas, were then combined and analyzed further to determine the optimum solution to the total problem. The resulting ATEC system is summarized in the following paragraphs.

This ATEC system is considered to be composed of numerous ATEC facilities. The ATEC system will evolve as a result of the implementation of these many ATEC facilities. The concepts contained herein are fully modular, so that a TCF can be provided full ATEC capability (all functions automated for all circuits and equipments), or provided only partial ATEC capability (only selected functions automated for all circuits and equipments, or for only selected circuits and equipments).

A number of selected, strategically located, major TCF's are to be provided full ATEC capability. Other key TCF's are to be provided partial ATEC capability, while still others are to remain entirely manual. Those TCF's which are provided full ATEC capability will provide the bulk of the monitoring and fault isolation, as well as coordination of major restorals. They will also serve as the DCS and OJCS reporting stations.

By locating fully implemented ATEC facilities at major nodes and by selecting a moderate number of such nodes, complete worldwide ATEC coverage will be achieved. These major-node ATEC facilities will then serve as a worldwide grid, coordinating the isolation of difficult faults, the restoral of degraded or failed service, and the rerouting of circuits and groups or supergroups. They will serve as direct interfaces with the DCA area or regional elements, and as such will serve as reporting stations. They will also have the processing and analysis capability for long term system performance status monitoring, and will determine and recommend changes or improvements required to obtain system optimization.

Where a TCF is provided full ATEC capability, its subordinate remote stations are also to be included. That is, RF transmitter and receiver sites, as well as tropo-scatter terminals, satellite earth terminals and repeater sites, are also to be implemented. Failure to implement all such remote sites will not prohibit proper ATEC operation, but will in effect reduce its efficiency and effectiveness.

Where a TCF is provided only partial ATEC capability, it may be provided with its own processor, or it may share the processor at another facility. Where such sharing is intended, the collected parameter measurements are telemetered via orderwire circuits to the processor location. The performance information derived from these measurements is then telemetered back to the originating station for display and operator action. This approach is also applicable to the remote sites, described above, which rely on the processor at the Technical Control facility.

Where a TCF remains totally manual, it will continue to operate in its present manner. It will benefit, however, from adjacent or nearby ATEC facilities since these facilities will detect circuit problems which are in fact caused by degradations within the manual TCF. Upon such detection, the ATEC facility will immediately notify the appropriate manual TCF so that action can be taken at that point. Further, the ATEC facility will coordinate significant problems and will handle reporting.

The ATEC facility is the key element in the ATEC System. In its full implementation, it provides for optimum semiautomation of even the largest TCF's. However, as already indicated, it can be implemented for any number of circuits

and/or equipment forms, is applicable to any size TCF — or for any functions of the TCF forms, is applicable to any degree at a given TCF. It is, however, more efficient and more effective (technically as well as economically) for large or medium size TCF's. The key features of the ATEC facility are as follows:

- Continuous in-service proof of performance
- Continuous in-service circuit monitoring
- Continuous in-service equipment and link monitoring
- Processor correlation of equipment, link and circuit monitoring information to provide Green, Amber and Red indications of near-real-time status and performance
- Automated fault detection
- Automated fault isolation
- Automated testing of digital and analog channels and circuits
- Processor controlled data storage (performance, status, data base, [illegible])
- Automated record keeping, logging and maintenance work order generation
- Simultaneous access to stored data and records
- Automated report generation
- Processor controlled displays employing CRT and teletypewriters
- Standardized operator positions for Status Monitoring, Quality Control and Technical Control
- Interchangeability of operator positions (any position capable of serving as any other position)
- Improved patch panels with normal through contacts
- Monitor and test jacks for circuit access via both operators and/or the processor
- Automated patching when required and/or justified at group, circuit and DC patch facilities

- Integrated orderwire and intercom
- Processor-to-processor data interchange between ATEC's
- Remote site monitoring and performance and status display
- Fully modular design, permitting phased implementation, i.e., selection of selected functions or selected circuits
- Standardization, resulting in the employment of the same modules, with only the type and quantity employed allowed to vary
- Full self-check capability, permitting various degrees of manual back-up, with full capability for totally manual operation.

A functional block diagram of the ATEC facility is presented in Figure [illegible]. This diagram provides clarification of the approaches to providing for the individual ATEC functions. The various functional areas may be listed as:

a. Circuit monitoring

b. Equipment/link monitoring

c. Test access and quality control

d. Fault isolation

e. Improved manual patching

f. Automated patching

g. Data base

h. Reporting and report [illegible]

i. Display and control operating consoles

j. Data processor

k. Control communications

Circuit monitoring is considered the most valuable and cost-effective of the various functions for automation. As mentioned earlier, circuit monitoring at a few selected major nodes can provide a reasonable degree of quality monitoring and fault isolation on a worldwide basis, thereby improving the performance of the worldwide communications system. Circuit monitoring is performed on a

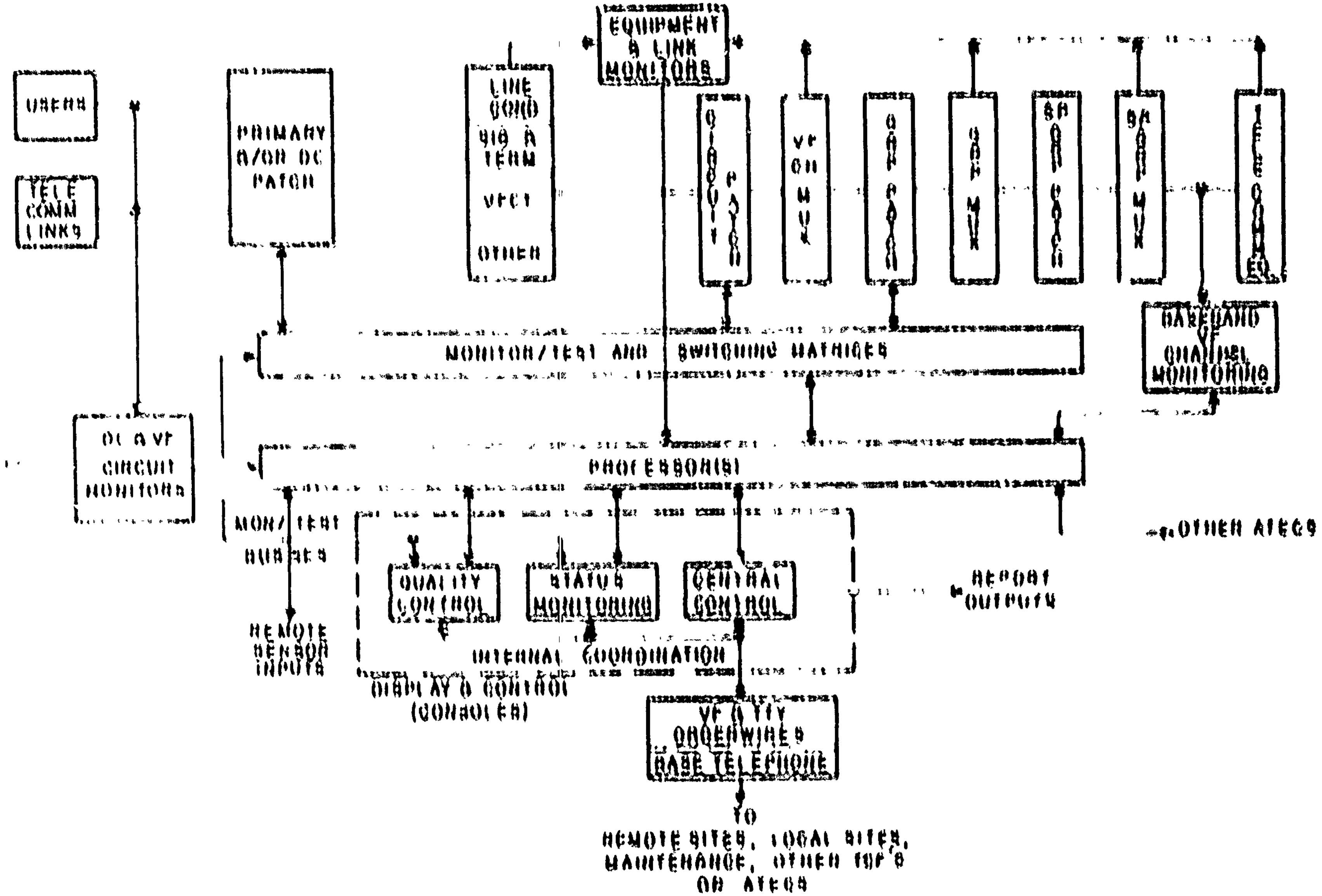

FIGURE 1 FUNCTIONAL BLOCK DIAGRAM OF ATEC FACILITY

continuous scan basis at the outputs of all circuits from the FTEC facility. That is, all VF and DC circuits egressing from the facility at the primary and at DC patch facilities are monitored on a nominal two-minute time interval. Likewise, all VF circuits (including those carrying digital information) egressing from the facility at the multiplex baseband, via radio or cable carrier, are demultiplexed to the VF channel level and monitored on a nominal two-minute time interval. Each VF circuit measurement involves a determination of the presence or absence of speech, and measurement of signal and noise levels. Each digital circuit involves detection of loss of transitions, and each teletypewriter circuit involves detection of loss of transitions and measurement of distortion. The various individual measurements are compared with prestored thresholds corresponding to the Green, Amber and Red conditions. The Amber and Red conditions will result in commencement of the fault isolation routine. Trend analysis will also be performed during Amber conditions, thereby providing a prediction of the time that either a Red or a Green condition will appear. The status and alarm information, as well as trend information, will be correlated with other status and alarm information so that only "real" faults will be displayed to an operator at the status monitoring display and control position. Preplanned and prestored restoral actions will also be displayed.

Equipment line monitoring involves monitoring selected key line and equipment parameters on a continuous scan basis, at a nominal two-minute interval. The specific parameters to be monitored are listed in Table III of Section III. Sensors are provided for each of the specified parameters, and their respective outputs are scanned. The resulting measurements are also compared with prestored Green, Amber and Red thresholds. Again, trend analysis will be performed during the Amber condition. The resulting fault information will be correlated with other fault information in order to provide only "real" alarm information to an operator at a status monitoring display and control position. Again, preplanned and prestored restoral action will also be displayed.

Monitor and test buses are provided so that an operator at a quality control display and control position or at a status monitoring position can manually access any desired circuit at its circuit patch appearance at primary patch appearance and at DC patch appearance as required. Sufficient test equipments are provided at each status monitoring position to permit fault verification and fault isolation. Additional test equipment is provided at the quality monitoring position to permit detailed testing for verification, isolation and acceptance. The capability provided by these monitor and test buses facilitates fault isolation within the FTEC facility and also permits assisting other TCF's in their efforts.

Automated fault isolation is also provided within the ATEC facility. It is a natural extension of the circuit monitoring and equipment/link monitoring functions already described. The automated fault isolation function is normally entered upon detection of a fault by the circuit monitoring function. When a fault is detected on an outgoing circuit at the baseband point, secondary measurements are made on that same circuit under processor direction and via the monitor and test buses. These secondary measurements are actually made at the circuit's circuit patch and primary patch appearances. Thus, the fault is isolated, i.e., between baseband and circuit patch, between circuit patch and primary patch, or external to the primary patch.

Similarly, if a fault is detected on an outgoing circuit via the normal continuous scan cycle at the point external to the primary patch, secondary measurements for fault isolation purposes are again made under processor direction. However, in this case the secondary measurements are made at the circuit patch appearance via the monitor and test bus, and at the baseband appearance via the baseband channel monitoring scanner. Hence, the fault is again isolated, i.e., between the initial point of detection (external to the primary patch) and the circuit patch or between the circuit patch and the baseband appearance.

Other assists to fault isolation are provided via the correlation capability of the processor, i.e., its ability to associate other status and fault information with the measurements obtained from the various sensors and scanners. Also, the quality control positions, as well as the status monitoring positions, can access the various appearances of the isolated circuit as discussed in a previous paragraph.

Only four types of patch bays are to be employed: group, circuit, primary and DC. New improved circuit patch panels equipped with normal-through jacks will be provided. Patch cord scanning will be provided under the control of the processor for purposes of patch verification and detection of existing patches. The manual patch panels are of particular significance in the event of complete fail-soft operation where all patching, as well as monitoring and testing, must be accomplished via the patch bays.

Automated patching or matrix switching is provided only for selected or most critical groups or circuits, thereby minimizing both the cost and size of the switching matrices. Reed relays will be employed for group switching, and solid-state, digital-compatible matrices will be employed for DC and circuit switching. Switching is not provided in any form or to any degree for the primary patch. The major impediment to providing automated patching is the high cost and large size. However, where justified by reasons other than direct dollar savings, it can be provided to any degree desired. In any case, the switching will be directed via the processor in response to operator commands from any of the display and control positions.

A data base is provided for both static and dynamic data. Static data such as configurations, normal set-ups, identifications and normal performance levels will be stored in a slide file for ready operator access, via a slide projector, at each operating position. Other static data, particularly all data needed by the processor to perform its operations, will be stored in memory storage. This data will include such items as threshold levels and actual performance data relative to requirements, links, trunks, groups and circuits.

Reporting and record keeping will be accomplished with the aid of the processor and the operator consoles. Both DOCR and O&M reporting will be handled. The processor will employ stored report formats and extract pertinent data from the data base. The partially completed report will be presented on the CRT display at the Central Control position for additions, deletions, modifications, approval and release by a Central Controller. The record keeping required by DCAC 310-70-[illegible], as well as other records deemed necessary for efficient and effective ATEC operation, will be generated and maintained by the processor. Where a specific format cannot be generated, an equivalent of the specific log form or record will be printed out. An activity log will be automatically generated at each operator position, and a Master Station Log will be generated at a Central Control position. Similarly, a chronological record of communications work orders will be provided in the maintenance area. Finally, all significant events will be stored on magnetic tape for later retrieval and analysis at a central off-line processing facility.

Three separate functional operating consoles will be provided: (a) Central Control, (b) Status Monitoring and (c) Quality Control. The Central Control position will serve as the supervisory position, and as such will maintain cognizance of the overall status of the facility and of the communications resources for which it is responsible. The operator at this position will be responsible for all major decisions, for report preparation and release, and for coordinating all program and data base changes. This position will also be responsible for system evaluation and analysis, for determining long-term and urgent remedies, for coordinating major restorals and for optimizing system performance. A second operator will perform these system functions at this position, for larger sites.

The Status Monitoring position will be responsible for link, equipment and circuit monitoring, for associated fault isolation, for coordinating with other DCS stations and with users for equipment substitution, and for preplanned circuit restorations and reroutes. In medium and large ATEC facilities, more than one Status Monitoring position may be required.

The Quality Control position will perform detailed testing of active and spare equipment, channels and circuits in order to detect degradations before they become failures. The operator at this position will perform acceptance testing of new and repaired equipment and circuits. He will assist the status monitoring operators by handling problems requiring lengthy fault isolation efforts, freeing these operators for other problems, and will temporarily assume the duties of a status monitoring operator in the event of abnormal problems.

Each of the operating positions will be similar in design, and, in fact, will be able to substitute for each other to meet contingencies and peak loads. Each position will include a CRT display, associated keyboard, a status reference file and a teletypewriter. In addition, it will include voice intercom and voice and teletypewriter orderwire terminals. The Central Control position will also have a high speed line printer. The Status Monitoring position will have a limited complement of test equipment, and the Quality Control position will have a more extensive complement of test equipment. Both types of positions will have monitor and test line access.

The required data processing capability will be comprised of a stored-program, small-scale processor with core memory, a mass storage file and a magnetic tape file. Programming will be fully modular, with standardized modules being employed. Programming and programming changes will be accomplished at a central location, from which distribution will be made to the various sites.

A voice intercommunications system within the ATEC facility will enable coordination of activities at consoles and equipment bays, and with maintenance forces and data orderwires conforming to the DCA policies expressed in DCAC 310-50-1 will satisfy the needs of the ATEC System for communications among DCS stations. ATEC facilities and other major radio stations will be tied together by orderwires. Adjacent sites will communicate over link orderwires. Communications to remote radio sites and major users will also be provided. Where express orderwires do not permit direct connections between widely separated ATEC facilities, the common-user AUTOVON network will be employed.

Processor-to-processor communications between ATEC facilities on the same express orderwire will be provided by applying a speech-plus-teletype capability to the voice express orderwire. Similarly, monitoring information from, and control data to, remote radio sites and unmanned repeaters will be carried over voice orderwires in a speech-plus-teletype mode.

Two-way communications for operational direction, coordination with, and reporting to DCOC elements will be enabled primarily by critical control circuits. When these are not available, common-user networks (AUTOVON and AUTODIN) will be used. Maintenance management circuits will be used for communications with O&M agency elements when available; otherwise, common user networks will be used.

SECTION III

ATEC SYSTEM CONCEPTS

1. BACKGROUND

1.1 The Defense Communications System

Major communications requirements of the Department of Defense (DOD) and other non-defense governmental departments and agencies are served by an extensive worldwide military communications network. The principal element of this system is the Defense Communications System (DCS), which consists of long-haul transmission facilities and associated switching centers. The DCS is controlled by the Defense Communications Agency (DCA) and is operated principally by the military departments.

1.2 Requirements for Technical Control

Every reasonable effort is made by the DCA and the military departments to design a very high degree of reliability and survivability into the system; however, all long-haul communications systems are subject to degradation and failure due to natural phenomena and normal equipment failure. One of the functions of Tech Control Facilities (TCF) is to alleviate the deleterious effects of such degradations and failures. Technical Control Facilities monitor the quality and functioning of the system and have prime responsibility in restoral actions involving loss of communications.

In its role as the controller of DCS stations, the TCF's interface with a designated DCA Operations Center Complex (DOCC) element, receiving operational direction from the DOCC and supplying status information to the DOCC. Certain of the DCS stations are designated as DCS reporting stations and submit near-real-time and periodic reports (ODR's) to the DOCC element, including reported-on stations for which reporting responsibilities may have been assigned. These reports fulfill the requirements of DCA Circular 310-55-1, "Operational Direction Manual of Defense Communications System (DCS)."

In addition to supporting the communications requirements of the DCS, the TCF is also responsive to the tactical needs of all military departments. Thus, communications resources are provided for many forms of service, such as ground/air, ship/shore and ground/ground as required for non-DCS service.

1.3 Functions of Tech Control

Technical Control can be broken down into three major categories:

a. Fault detection and isolation
b. Restoral of service
c. Record keeping and reporting

These functions in today's TCF's are performed primarily by manual procedures, and in some cases are aided with small degrees of semiautomated quality monitoring.

1.3.1 Detection of Degradation and Failure

In order to carry out his responsibilities, the Technical Controller must be alerted when a circuit is in trouble. Trouble may be defined as the delivery of an unsatisfactory signal to the user or the presence of an abnormal condition in a station or on a transmission link, which, if not corrected, will result in an unsatisfactory signal to the user. The objective of the Technical Controller is to prevent or minimize the unsatisfactory user service on the circuits under his cognizance. The degree to which he is able to accomplish this objective is determined to a large extent by the tools at his disposal. His tools, in terms of the Technical Control facilities provided for his use, must be designed to inform him promptly of any and all trouble affecting his circuits and to aid in correction.

There are a number of ways in which a Technical Controller becomes aware of circuit troubles. The simplest but least desirable is for the user to inform the Technical Controller that the service is unsatisfactory. An alternative is for the Technical Controller to monitor the quality of the signals being transmitted from his station.

1.3.2 Fault Isolation

When a trouble is detected on a circuit, the function of the Technical Controller is to locate the fault and take corrective action. It is essential to the proper operation of a Technical Control that faults be quickly isolated and corrective action effected. In some cases, the trouble may not have caused immediate loss of service to the user; however, speed in isolating the fault is important to avoid service being affected.

1.3.3 Service Restoral

After detecting a fault and isolating it to an element of the communications system, the Technical Controller is responsible for restoral of service. To carry out this responsibility, the Technical Controller has facilities for patching spare equipments and limited amounts of spare circuits for immediate restoral. Other situations may require maintenance actions to effect restoral; also, in those cases where circuit priority justifies such actions, lower priority users will be preempted to effect restoral.

1.3.4 Reporting

Reporting and log keeping are necessary but time-consuming functions for a Technical Controller. Reporting requirements for Technical Control are established by the DCA in DCAC 310-55-1, "Operational Director Manual of Defense Communications Systems (DCS)", and by the O&M agencies of the various military departments in such documents as "Navy Operations Reporting Requirements for Automated Technical Controls" for the Navy, and AFCSR 100-17 for the Air Force. Although the ATEC study group did not receive any Army documents covering their reporting requirements, it is understood that they are similar to those of the Navy and the Air Force.

2. REQUIREMENT FOR AUTOMATION

The ever-increasing work loads placed on the Tech Control facilities of the DCS, due to growth and the increasing use of high speed digital transmission, have highlighted deficiencies in the present system. The future trend toward more and higher speed digital transmissions, with the attendant stringent performance requirements, and the problem of obtaining and retaining the required quantities of skilled personnel are causing this situation to worsen. In order to cope with the present-day situation and accommodate the growth rate of the system, action must be taken now in order to prevent the technical control facilities from becoming the bottleneck of the system. The present-day Tech Controller is burdened with the task of attempting to perform his duties with the tools and facilities of his trade, which have not kept pace with the technical advancements made in the systems which he attempts to control. These facilities and his tools have changed very little from those used in World War II, and are simply not adequate to cope with the present situation. An attempt to solve the problem has been made by adding more and more manpower; however, this solution is not cost-effective and has not solved the problem, and in most cases, because of chronic skilled manpower shortages, the facilities could not be staffed to authorized levels.

All of the functions of Technical Control delineated in paragraph 1.3 are candidates for automation. The following paragraphs describe ways in which automation may be applied to the performance of these functions in order to obtain a significantly more effective facility capable of implementation within present state-of-the-art technology.

2.1 Fault Detection and Isolation

The primary mission of the DCS Technical Control facility is to assure optimum communication services for users. Provision of optimum service

requires that Tech Control personnel be aware of the real-time total communication performance, and make use of this knowledge to prevent or correct unsatisfactory service.

Communication performance can be obtained by a monitoring function which is composed of subfunctions as follows:

- Equipment
- Link
- Circuit
- System status

The first three subfunctions can be accomplished by direct monitoring of accessible communication resources, and the fourth, system status, may be derived by analysis of the first three. In present TCF's, the status monitoring function is limited by the capability and capacity of the manual operators; they frequently must rely upon notification from users of unsatisfactory service. Therefore, automation of monitoring for performance assessment and failure prediction is considered of primary importance in the ATEC facility.

To accomplish equipment, link and circuit monitoring involves (a) the selection of parameters capable of effectively evaluating performance, (b) measurement of these parameters without interruption to, or degradation of, normal service, (c) orderly collection of the results of these measurements, (d) association, analysis and evaluation, (e) presentation of results, (f) acquisition of additional relevant data, if required, (g) decisions, and (h) initiation of action.

The objective of ATEC is to automate the actions listed in (a) through (e), and provide tools to assist the operator in (f) through (h). The remainder of this discussion is devoted to the considerations and analyses related to the effective accomplishment of this automation.

2.1.1 General Considerations

The ATEC system must provide a maximum return for every dollar invested, and, since a minimum deployment of ATEC facilities within the DCS can provide a highly significant performance improvement, the presumption of an initial minimum deployment of ATEC facilities within the DCS is reasonable. Sufficient and strategic circuit status monitoring can provide information relative to all circuits (drop and through circuits) at an ATEC facility. In addition, information relative to the performance of other TCF's is also obtained.

The important point is that faults are detected on all circuits entering and leaving the facility, regardless of the location of the fault. Circuit monitoring can, of course, detect faults that exist between the ATEC facility and the originator (sending user). In this case, fault detection and assistance in fault isolation of a trouble can be accomplished on a circuit where the distant user may be hundreds or thousands of miles away; thus, the ATEC facility detects faults on circuits for which it is not the servicing TCF.

Equipment measurements can provide equipment status and, in addition, information relative to the overall performance assessments of the ATEC. Detecting faults (degradation or failure) within the equipments when a fault occurs provides immediate isolation of the problem. Increasing the number of parameters to be measured in an individual equipment could further isolate the fault to elements of the equipment. However, this is not cost-effective or necessary for efficient technical control at a station. In most instances, restoral of service is not dependent upon immediate repair of the failed equipment

Equipment fault detection is required in selected equipments to provide significant technical information for control of communications facilities.

The equipment parameters selected for measurement must contribute significantly to the detection of equipment faults and to the assessment of the communications performance of the station. Those equipments that support large numbers of communications circuits are primary targets for monitoring in the ATEC facility. The status monitoring of these equipments will provide an effective information source with minimum application of resources. These equipments include wideband communications equipments such as multiplex, line-of-sight radio terminals, tropo radio terminals and satellite earth station terminals. The parameters which have been selected for measurement are those which will provide optimum performance information.

The combination of circuit monitoring and limited but significant equipment monitoring in conjunction with correlative processing of the data obtained provides the optimum approach to fault detection and isolation at the system, link, circuit and equipment levels.

2.1.2 Selection of Parameters

The initial identification and selection of parameters to be monitored were made by the individual study task groups. These parameters, as well as the accompanying rationale and justification for their selection, are contained in the following sections of this report: Section VII, Link Status and Monitoring;

Section VIII, Equipment Status and Monitoring, and Section IX, Circuit Status Monitoring. The parameters selected therein are tabulated in Table II. The parameters identified in the second column of the table are classified as secondary; all others are considered primary. The classifications of primary and secondary were established by the study task groups, and indicate only that primary parameters are of greater importance for measurement than secondary parameters. The secondary parameters are included in this table for review. The final objective is to establish a minimum set of measurable parameters which are optimum for the ATEC system.

2.1.3 Optimization of Parameters

The parameters listed in Table II were reviewed, analyzed and evaluated by members of the individual task groups and the system analysis group. The basis for evaluation was technical and cost effectiveness relative to the objective of the ATEC system.

The resultant parameters recommended for measurement in the ATEC facility are listed in Table III.

The circuit status monitoring parameters are basically unchanged from those of Table II, except for digital circuits. No-transition detection was added to both the low and high speed digital circuit parameters to permit detection of service anomalies. Synchronization and out-of-service distortion were also added to the high speed digital circuit parameters to permit fault detection and fault isolation.

The following changes were made to the parameters listed in Table II in order to optimize the equipment monitoring requirements.

a. All of the primary in-service parameters for monitoring of the HF transmitter and receiver were retained. The secondary parameters identified as VF channel input and output levels are also required for fault detection and fault isolation of HF equipment/circuit problems. The VF channel input to the transmitter provides the last point for observing signal level characteristics prior to transmission.

   At the HF receiver, VF channel level provides the first monitor point for detecting received signal. The HF transmitter and receiver performance assessors are not required for the operation of the ATEC system. They would provide expedient assistance for the maintenance and diagnosis of the HF equipment, and are included for consideration as maintenance equipments. The ATEC system

Table III - Parameters Selected for Status Monitoring

FUNCTION/PARAMETER	SECONDARY PARAMETER	SERVICE STATUS IN	SERVICE STATUS OUT	REMARKS
1. Circuit Status Monitoring				
a. Analog Circuit				
(1) Signal Level		X	X	Out of service testing performed by multi Parameter test set
(2) Noise Level (Total)		X	X	
(3) Phase Jitter			X	
(4) Amplitude-Frequency Response			X	
(5) Maximum Change in Audio Frequency			X	
(6) Envelope Delay Distortion			X	
(7) Impulse Noise			X	
b. Digital Circuit				
(1) Low Speed				
(a) Total Distortion (Peak)		X	X	Out of service testing performed by distortion measuring test set
(b) Speed (Baud Rate)	X		X	
(2) High Speed				
(a) Bit Error Rate			X	
(b) Impulse Noise			X	Out of service testing performed by Multi Parameter test set and measurements made on Analog Signal of high speed digital circuit
(c) Noise Level (Total)			X	
(d) Isochronous Distortion (Jitter)			X	
(e) Envelope Delay Distortion			X	
(f) Frequency Response			X	
2. Equipment Status and Monitoring				
a. HF Transmitter				
(1) Forward Power		X		
(2) Reflected Power		X		
(3) Major-Minor Alarm		X		
(4) VF Channel Input	X	X		
(5) Frequency Accuracy	X	X		
(6) Gain			X	Out of service performance assurance
(7) S/N Ratio			X	
(8) Intermodulation Distortion			X	
(9) Frequency Translation			X	
(10) Carrier Suppression			X	
(11) Intermodulation Products			X	
(12) Response Characteristics			X	

Table XI - Continued

FUNCTION/PARAMETER	SECONDARY PARAMETER	SERVICE IN	SERVICE OUT	REMARKS
b. HF Receiver				
(1) Receive Signal Level (AGC)		X		
(2) Major-Minor Alarm		X		
(3) VF Channel Output	X	X		
(4) Local Osc./Synthesizer Level	X	X		
(5) Frequency Accuracy	X	X		
(6) S/N Ratio			X	
(7) Intermodulation Distortion			X	
(8) Frequency Translation			X	Out of service performance assessed
(9) Intermodulation Products			X	
(10) Response Characteristics			X	
c. Los-Tropo Radio Terminals				
(1) Radio Continuity Tones (Pilot)		X		Tx & Rx
(2) Noise (Out of Band)		X		Rx
(3) Receive Signal Level (AGC)		X		Rx
(4) Output Forward Power		X		Tx
(5) Reflected Power		X		Tx (Tropo only)
(6) Major-Minor Alarm		X		Tx/Rx
(7) Service Channel Level	X	X		Tx & Rx
(8) Baseband Signal Level	X	X		Tx & Rx
(9) Local Receive Oscillator Level	X	X		Rx
(10) Frequency Accuracy	X	X		Tx
(11) Combiner Performance (Squelch)	X	X		Rx
(12) Klystron Drive Output	X	X		Tx
(13) Klystron Performance (Beam Current)	X	X		Tx
(14) TWT Performance(Beam & Helix Current)	X	X		Tx
d. Satellite Earth Terminal				
(1) Up Converter Signal Level		X		Tx
(2) Power Amplifier Input		X		Tx
(3) Antenna Feed Forward Power		X		Tx
(4) Antenna Feed Reflected Power		X		Tx
(5) Down Converter Output		X		Rx
(6) Receive Signal Level		X		Rx
(7) Radio Continuity Tones (Pilot)		X		Tx & Rx
(8) Antenna Positioning Servo Input		X		Tx & Rx

Table II -- Continued

FUNCTION/PARAMETER	SECONDARY PARAMETER	STATUS IN	STATUS OUT	REMARKS
d. (9) Major-Minor Alarm		X		Tx/Rx
cont)(10) Critical Band Noise		X		Rx
(11) Synchronization Errors		X		Rx (For FSK only)
(12) Correlation Errors		X		Rx (For spread spectrum only)
(13) Up Converter Frequency Lock	X	X		Tx
(14) PA Forward Power	X	X		Tx
(15) PA Reflected Power	X	X		Tx
(16) Down Converter Frequency Lock	X	X		Rx
(17) Tracking Receiver Output Signal Level	X	X		Rx
(18) Tracking Receiver Output Noise Level	X	X		Rx
(19) Tracking Receiver Signal Level (AGC)	X	X		Rx
(20) Tracking Receiver Frequency Lock	X	X		Rx
(21) Baseband Inputs and Outputs	X	X		Tx & Rx
e. VF Carrier FDM				
(1) Receive Group Signals		X		Rx
(2) Group Pilot Tones		X		Rx
(3) System Pilot Tones		X		Tx & Rx
(4) Major-Minor Alarm		X		Tx/Rx
(5) Carrier Oscillator Stability	X	X		Tx (May be included in Major-Minor Alarm)
f. Time Division Multiplex (TDM)				
(1) Bit Error Rate		X		Rx
(2) Synchronization		X		Rx
(3) Major-Minor Alarm		X		Tx/Rx
g. VF Carrier Telegraph (VFCT)				
(1) Digital Signals		X		
(2) Composite VF Signal Level		X		
(3) Major-Minor Alarm		X		Tx/Rx
h. Data Line Modem				
(1) Analog Signal Levels		X		
(2) Bit Error Rate		X		Rx
(3) Synchronization		X		Rx
(4) Major-Minor Alarm		X		Tx/Rx
i. Telegraph Regenerative Repeater				
(1) Major-Minor Alarm		X		

Table II - Continued

FUNCTION/PARAMETER	SECONDARY PARAMETER	SERVICE STATUS IN	SERVICE STATUS OUT	REMARKS
j. Radio-Telephone Terminal				
(1) Major-Minor Alarm		X		
k. Telephone Signaling and Termination Set				
(1) Major-Minor Alarm		X		
l. Line Conditioning Equipment				
(1) Major-Minor Alarm		X		
m. Rectifier Station Battery				
(1) Rectifier DC Output		X		
(2) DC Bus Voltage		X		
(3) Major-Minor Alarm		X		
n. Rectifier Charger-Wet Cell Station Bat				
(1) DC Bus Voltage		X		
(2) Major-Minor Alarm		X		
o. Uninterrupted and Auxiliary Power System				
(1) Major-Minor Alarm				
3. Link Status and Monitoring				
a. Transmit Signal Parameters				
(1) RF Forward Power		X		
(2) RF Reflected Power		X		
(3) RF Spectrum		X		HF, Tropo, and Satellite
(4) Modulation Index (level)		X		
(5) Baseband Signal Level		X		
(6) Radio Continuity Tone (pilot)		X		
(7) Amplitude Differential (group pilot)		X		
(8) Baseband Spectrum		X		
(9) Composite VFCT Level (VF channel input)		X		HF only
(10) IF Signal Level	X	X		Tropo and Satellite only
(11) IF Spectrum	X	X		
b. Receive Signal Parameters				
(1) RF Spectrum		X		
(2) IF Signal Level (receive AGC Level)		X		

Table III Concluded

FUNCTION/PARAMETER	SECONDARY PARAMETER	SERVICE STATUS IN	SERVICE STATUS OUT	REMARKS
b. (cont.)				
(3) IF Spectrum		X		
(4) Radio Continuity Tone (Pilot)		X		
(5) Noise (Out of Band)		X		
(6) Amplitude Differential (Group Pilot)		X		
(7) Baseband Spectrum		X		
(8) Composite VFCT Level (VF Channel Output)		X		HF only
(9) Framing Error Rate		X		TDM only
(10) Bit Error Rate		X		For error detection and correction or error detection equipment
(11) Predecision Waveform		X		For PSK on Satellite only
(12) Link Orderwire Error Rate			X	For SS on Satellite only
(13) Correlation Waveform		X		For SS on Satellite only
(14) RF Noise Level	X	X		Satellite only
(15) RF Gain	X	X		
(16) IF C/N or C/KT	X	X		Satellite only
(17) Baseband Signal Level	X	X		
(18) Framing Synchronization	X	X		TDM only

Table III - Parameters Recommended for Status Monitoring

FUNCTION/PARAMETER	SERVICE STATUS		MEASUREMENT TECHNIQUE	REMARKS
	IN	OUT		
1. Circuit Status Monitoring				
a. Analog Circuit				
(1) Signal Level	X	X	In-service scanning of VF channels at baseband and user drop	These measurements are made on all analog circuits and are very pertinent to high speed digital circuit performance.
(2) Noise Level (total)	X	X		
(3) Jitter (phase & isochronous)		X	Out-of-service use of multi-parameter test transmitter & analyzer.	
(4) Amplitude-Frequency Response		X		
(5) Maximum Change in Audio Frequency		X		
(6) Envelope Delay Distortion		X		
(7) Impulse Noise		X	Impulse Noise test set.	
b. Digital Circuit				
(1) Low Speed				
(a) Total Distortion (peak)	X		In-service scanning of DC circuits at user drop and at composite VFCT tones by converters and distortion measuring test set.	
(b) No Transition	X			
(c) Bias, Speed & Total Distortion		X		
(2) High Speed				See measurements made on analog circuits.
(a) Bit Error Rate	X	X	Bit error rate tester for out-of-service test. Existing equip. sensors for in-service mon. and distortion measuring test set.	
(b) Synchronization	X			
(c) No Transition	X			
(d) Bias, speed & Total Distortion		X		

Table III - Continued

FUNCTION/PARAMETER	SERVICE STATUS IN	SERVICE STATUS OUT	MEASUREMENT TECHNIQUE	REMARKS
2. Equipment Status and Monitoring				
a. HF Transmitter				
(1) Forward Power	X		Equip. sensor	To use existing or furnish sensors
(2) Reflected Power	X			
(3) VF Channel Input Level	X			
(4) Major-Minor Alarm	X		Existing Alarms	
b. RF Receiver				
(1) Receive Signal Level (AGC)	X		Equip. sensor	To use existing or furnish sensors.
(2) VF Channel Output Level	X			
(3) Major-Minor Alarm	X		Existing Alarms	
c. LOS Tropo Radio Terminal				
(1) Forward Power	X		Equip. sensor	TX TROPO only
(2) Reflected Power	X			TX
(3) Baseband Signal Level	X			TX To use existing or furnish sensors
(4) Radio Continuity Tone (pilot)	X			RX
(5) Noise (out of band)	X			RX
(6) Receive Signal Level (AGC)	X			RX
(7) Combiner Performance (squelch)	X			RX
(8) Major-Minor Alarm	X		Existing alarms	TX/RX
d. VF Carrier FDM				
(1) Group Pilot Tones (all groups)	X		Equip.sensor	RX To use existing or furnish sensors
	X			
(2) Major-Minor Alarm			Existing alarms	TX/RX
e. Time Division Multiplex TDM				
(1) Bit Error Rate	X		Existing sensors	RX Only one actually reqd. No.2 preferred if both available.
(2) Framing Error Rate	X			RX
(3) Framing Synchronization	X			RX
(4) Major-Minor Alarm	X			TX/RX To be available from equipment as in-service sensor alarms

Table III - Continued

FUNCTION/PARAMETER	SERVICE STATUS IN	SERVICE STATUS OUT	MEASUREMENT TECHNIQUE	REMARKS
f. Data Line Modem				
(1) Bit Error Rate	X		Existing sensor	RX When available
(2) Synchronization	X			RX
(3) VF Carrier (loss of carrier)	X			VF-TX To be available from equipment
(4) No Transition	X			DC-TX as in-service sensor alarms.
(5) Major-Minor Alarm	X			
g. Major-Minor Alarm				
(1) VF Carrier Telegraph	X		Existing alarms	To use available alarms
(2) Telegraph Regenerative Repeater	X			
(3) Radio Telephone	X			
(4) Telephone Signaling and Termination Set	X			
(5) Line Conditioning Equipment	X			
(6) Station Battery Rectifiers	X			
(7) Uninterrupted and Auxiliary Power System	X			
3. Link Status and Monitoring				
a. Transmit Signal Parameters				
(1) RF Forward Power	X		Equip. sensor	Equipment sensors used for link performance assessment.
(2) RF Reflected Power	X			
(3) Baseband Signal Level	X			
(4) VF Channel Level (for HF transmitter)	X			
b. Receive Signal Parameters				
(1) Radio Continuity Tones (pilot)	X		Equip. sensor	Equipment sensors used for link performances assessment.
(2) Receive Signal Level (AGC)	X			
(3) Amplitude Differential (group pilot tones)	X			
(4) Noise (out of band)	X			
(5) VF Channel Level (for HF Receivers)	X		Equip. Sensor	
(6) Bit Error Rate	X		If available from EDC or ED equip	6 is preferred over 7 & 8 if avail from EDC or ED equipment.
(7) Framing Error Rate	X		equip. sensor	7 is second choice if 6 is unavailable. 8 is third choice if 6 or 7 is unavailable.
(8) Framing Synchronization	X			

Table III - Concluded

FUNCTION/PARAMETER	SERVICE STATUS		MEASUREMENT TECHNIQUE	REMARKS
	IN	OUT		
c Satellite Earth Terminals	X	X	Measurements made at earth terminal stations	Status information to be furnished from Satellite Earth Terminal to ATEC for the links being utilized.

operational and functional requirements do not justify the need for these off-line assessors in view of the present trends toward increased wideband communications requirements and decreased HF requirements. The performance assessors have application in special situations, such as air/ground, ship/shore and associated maintenance needs.

b. The primary parameters (Table II) identified for monitoring of the LOS-TROPO radio terminal equipment are all required for the operation of the ATEC system. Two secondary parameters, baseband signal level (transmit) and combiner performance, are required for effective performance assessment and fault detection. The transmit baseband signal level measurement provides for detection of excessive signal levels, which cause overmodulation and distortion of the transmitter. The combiner performance measurement detects the loss of a path in a diversity link. It also provides the means, in conjunction with the receive signal level (AGC) measurement, for detecting improper combiner operation.

c. The satellite earth terminal parameters listed in Table II do not appear in Table III. The parameters identified (Table II) for measurement at the satellite earth terminal are commensurate with the parameters identified for measurement of other equipment/link status and performance. The present Defense Satellite Communication System (DSCS) planning for the satellite earth terminal includes the requirement to monitor most, if not all, of the parameters which have been identified. It is also intended that the information be processed at the earth terminal for efficient and effective control of the satellite communications transmission equipment. Information collected at the earth terminal, which is pertinent to the functional operation and control of an ATEC facility, should be passed to that facility. The type of information required would be the real-time status of the links used to support the ATEC facility transmission needs. Short and long-term trends and performance analysis should already be planned as part of the earth terminal processing of the status information. It is recommended that initially the status information be transferred to an ATEC facility via manual coordination, employing orderwire capability, required between the ATEC facility and the satellite earth terminal station. When satellite communications become more predominant, and the operational control at the earth terminal station is more firmly established, the transfer of the pertinent status information should be automated (processor-to-processor) between the two facilities.

d. Only two of the four primary parameters identified in Table II for monitoring the VF carrier FDM are required for the ATEC system. These are receive group pilots and major-minor alarm. The receive group signal level measurement is not required, since all VF channel breakouts are to be measured at the user drop, and all through groups are to be measured on an individual channel basis at the transmit baseband. Measurement of the system pilot tone would be redundant with the measurement of the radio continuity tone and group pilot tones. The secondary parameter of carrier oscillator stability should be included in the major-minor alarm.

e. All of the TDM parameters identified for monitoring are required for the ATEC system. The parameter entitled "synchronization" was expanded to two measurable parameters: framing error rate and framing synchronization. Only framing error rate need be measured when they are both available.

f. The data line modem parameters are basically unchanged. The analog signal level parameter identified in Table II is to be measured by circuit status monitoring. Loss of carrier (VF transmit) and no transitions (DC transmit) have been established for measurement when sensors are available in the equipment. These parameters will detect faults in the modem equipment and assist in fault isolation. Some modems have bit error rate sensing available from the encoding/decoding scheme used in the modulation technique. This parameter should be used for circuit performance assessment when it is available.

g. The available major-minor alarms of all equipments will be monitored to provide immediate detection of equipment faults and rapid isolation of problems.

h. Link monitoring is derived from information obtained from certain sensors, which, in most cases, are also used for the equipment parameters being monitored. Link status includes performance assessment of the equipments supporting the links; path information is obtained from collating and analyzing measurements of certain equipment parameters. The link status and monitoring requirements were, however, evaluated separately from equipment status and monitoring (see Section VII). During the later collaboration effort of the study task groups, it was determined that all of the link status information could be obtained from the identified equipment parameters. Those few parameters that could not be derived from

other parameter measurements and correlation techniques were not cost-effective to implement, since link or path faults account for less than 1 percent of the total outage time due to all faults.

2.1.4 Parameter Measurement and Information Collection

Techniques for measurement of the various parameters (in Table III) were investigated in detail by the appropriate individual study task groups. These efforts and results are documented in detail in Sections VIII and IX. The methods developed therein rely primarily on sampling and scanning techniques. That is, either: (a) a sensor is dedicated to the measurement of a specific parameter at a particular point, and the outputs of many such similar sensors are scanned and relayed to the processor, or (b) a large number of similar points requiring monitoring are scanned, and the output of the scanner is provided to a single sensor; its output, in turn, is relayed to the processor. The primary reason for employing scanning, or sampling, as opposed to continuous full-time monitoring of all points is the high cost which would result from the large number of monitoring devices required.

A scan interval of two minutes is considered optimum, and was based upon a number of considerations:

a. Detect degradation of service or change in state prior to user complaint.

b. Detect degradations or failures and permit correction prior to need for reporting (correction within 10 minutes of time that outage began).

c. Establish trends by analyzing parameter measurements as a function of time.

d. Employ existing state-of-the-art hardware for scanning and monitoring.

Relative to the first two items above, a time interval of less than 5 minutes is desirable. Such a time interval would also satisfy the third consideration. With respect to available hardware and techniques, it was determined that for one of the largest sites (e.g., Fuchu), all of the required parameters can be monitored in a time period on the order of one minute. The capability for accomplishing this task in a one-minute period takes into account the scanner operating times, the sensor dwell time and the A/D conversion times. While a one-minute time interval is considered feasible, it is desirable to incorporate

some design safety factor, as well as to provide for expansion (adding more sensors). Hence, a two-minute interval (for scanning all sensors at a largest site) is realistic. Relating this two-minute interval, then, to items a, b and c above indicates that it is also adequate for those requirements. That is, with a total scan cycle of two minutes, the average time to detect a service degradation or change of state will be one minute. Hence, it is unlikely that a user complaint will be received prior to fault detection. Also, adequate time will be available to correct the problem before reporting is required (based on reporting after ten minutes of outage) and adequate measurements are obtained (at two-minute intervals) for trend analysis. Finally, to accomplish scanning at a rate exceeding the once-per-two-minutes would require additional hardware complexity and quantity, and would provide no real gain in monitoring performance.

Where the processor is located in the general vicinity (within hardwire transmission distance) of the sensors and scanners, the collected measurements can be connected directly to the processor. However, when the sensors and scanners are located remotely, transmission techniques must be employed. This facet of data collection is covered in Section XII, Telemetry Analysis.

The remote sites recommended for the monitoring of status information are the repeaters and HF transmitter and receiver sites connected to, and under the operational control of, the ATEC facility. The equipment will be monitored at these sites, and the parameter measurements sent to the ATEC facility for threshold detection and analysis of the data. All fault conditions, detected at the ATEC facility for equipment at a manned remote site, will be transmitted back to the remote site for printout on a teletypewriter. Threshold detection must be performed in the processor because the parameter measurements do not result in go - no go indications. The measurements are actual variations of the parameter values over the range of normal, degraded and failed operation of the equipment.

2.1.4.1 Equipment/Link Measurements

The majority of the equipment/link parameters selected require the design of sensors to detect the parameter variations. Design requirements are investigated in detail in Section VIII. The sensor types required are identified by the signals they will monitor, i.e., DC, AF (audio frequency), RF and MW (microwave). The sensors identified as existing (in Table III) will usually be available in some form in the equipment, but in some cases will require interfacing equipment. In certain cases sensing is not feasible. For example, some of the parameters identified as candidates for data modems are in this category. In this case, the VF signal level (loss of carrier) and no transition measurements accomplished by the circuit monitoring equipment will suffice.

Equipment/link parameters will require that some sensors be dedicated to each point being monitored, because low level and high frequency signals cannot be cabled over any significant distance or scanned without introducing significant attenuation or distortion.

Within the ATEC facility, all of the equipment/link parameters will be scanned and the status information passed to a processor for threshold detection. The alarm information (threshold crossings) are then analyzed and presented to an operator. The scanning equipment must be under direct control of the processor in order to permit complete control (i.e., stop, start, homing and repeat).

Equipment/link monitoring will also be performed at remote sites, which are under the operational control of the ATEC facility. The status information obtained at the remote location will be returned by telemetry, via the speech plus service channel, to the ATEC facility for processing. All alarm conditions will then be returned to manned remote sites by the return transmission path, and printed out on a teletypewriter. The remote scanning will also be under the control of the ATEC facility processor. The circuit used to return status information to the remote site will also be used for the control of the scanner. The circuit required for exchange of information between the remote site and the processor at the ATEC facility will normally be a full-duplex, 75 baud teletypewriter channel.

2.1.4.2 Circuit Measurements

The in-service circuit monitoring parameters consist of two types: (a) those that involve monitoring of the actual signals on the circuit and (b) those that involve monitoring performance alarms which are included in equipments such as modems, TDM and ED&C equipment. The former type includes signal level, noise level and total distortion measurement. The latter type includes no transitions bit error rate or synchronization. Both types of parameters will be measured on a scan basis. Where equipment sensors are not available for detection of no transitions, the equipments employed for monitoring of the actual signal on the circuit will detect this condition.

VF transmit channel measurements will be accomplished at the multiplex baseband output on a continuous scan basis. These measurements will assess the quality of the signals leaving the ATEC facility. Adverse signal characteristics detected will be further isolated to the ATEC facility equipment, or to the signal entering the facility, automatically by other circuit monitoring locations under processor control. For example, if the circuit is from a local user, the send line from the user will be automatically selected at both the primary and circuit patch facilities simultaneously by a monitor/test bus, and

a measurement made through a scanner. If the signal characteristics are degraded at the primary patch, an operator will be advised. The user may then be notified of the condition. If the user signal is acceptable at this point, a problem exists in the line conditioning equipment or VF channel multiplex within the ATEC facility, and an appropriate indication will be provided to the operator. The measurement made at the circuit patch will further isolate the problem to either the line conditioning equipment or the VF channel multiplex equipment. Through circuits, demultiplexed to the VF channel level, will also be checked as just described. However, if the through circuit is demultiplexed only to the group or supergroup level, the VF channel will be measured (under processor command) at the receive multiplex baseband (the point where the signal enters the facility). In this case, then, by employing continuous scan monitoring at the transmit baseband, and making measurement on command at the receive baseband, a detected fault can be isolated to either in-station or out-of-station.

Similarly, continuous scan monitoring will be accomplished at the VF channel and DC circuit break-outs, or drops, to the users (outgoing channels relative to the ATEC facility). Detection of degradation at these points will result in automatic selection, by the processor, of the corresponding VF channel at the multiplex baseband. The result of the measurement at this point will isolate the fault as being either within the ATEC facility (between user drop and multiplex baseband) or external to the ATEC facility. When VFCT equipment exists at the ATEC facility, the send composite VF signals will be continually scanned, converted back to DC signals, and each digital transmit signal scanned and monitored for total peak distortion; thus any faults within the VFCT equipment will be detected. Also, the processor will automatically select the receive composite VF signals for fault isolation where a fault has already been detected on the DC circuit of the user drop (user receive line). If the ATEC facility VFCT monitoring equipment is compatible with the user VFCT equipment, the user send lines containing VFCT composite signals can also be monitored.

Circuit status information is available at automatic message switching and circuit switching facilities, such as those within the AUTODIN and AUTOVON. The AUTODIN facility obtains status information via program error detection capabilities within the message switching processor. This status information relative to the AUTODIN high speed data circuits is significant. The information available is applicable to both user circuits and trunks between Automatic Digital Message Switching Centers (ADMSC's) serviced by the ATEC facility. Where the AUTODIN ADMSC is not connected to the ATEC facility, but high speed data users of AUTODIN are connected, information can be obtained directly from the user for the circuits serviced by the ATEC facility.

The AUTOVON facilities have an inter-switch routiner which automatically tests the trunks between AUTOVON facilities. At an ATEC facility where the AUTOVON is a connected user, information regarding the trunk status will assist ATEC in maintaining performance status and in responding to problems detected by these AUTOVON tests.

Both the AUTODIN and AUTOVON switch information will be of value to an ATEC facility. Initially, only manual transfer of this information will be justified, to obtain a measure of its true value to the ATEC operation and to determine the reaction requirements at the ATEC facility. Ultimately, it is anticipated that this information in real-time will prove valuable to the ATEC facility, and that the required programming and interface modifications of the AUTODIN and AUTOVON facilities will be justified.

2.1.5 Information Processing

All of the status (parameter measurement) information obtained from equipment sensors and circuit measurements must be analyzed to determine whether the parameter reading is indicated as a normal or a degraded condition. This could be accomplished by operators, but when hundreds or even thousands of measurements are being made every few minutes, it becomes an impracticable task for humans. The information must be analyzed for detecting predetermined threshold crossings, making trend predictions and isolating faults by correlation with other information associated with the same equipment and circuits. In addition to the information analysis, records must be maintained on all failures and corrective actions performed at the TCF. This analysis and processing of the parameter measurements is accomplished by a software programmable processor. The functions to be accomplished and the means of accomplishing them are contained in the immediately following text and in Section IV, X and XV.

2.1.5.1 Threshold Detection

Three conditions have been defined to depict the operational status of the equipment/links and circuits. These status conditions are referred to by color, for distinction. Green represents the normal condition where the parameter being measured is within the operational and/or design standard value for the equipment or circuit. Amber represents an abnormal condition where the parameter being measured is degraded and below the operational and/or design standard value. When the Amber condition exists, user service may not be impaired, but a continuation of degradation will eventually affect user service. Red represents an inoperative condition where the parameter being measured indicates a failure of the equipment and/or circuit. In this case user service

has been interrupted or service has degraded to an unusable state.

Green will be understood in the absence of Amber and Red, and the Green condition will not be displayed. If an operator wants an actual parameter measurement value, it can be obtained by request and identification of the sensor for which the reading is required. Actual parameter measurements will be obtainable from any sensor monitoring other than a binary condition. Normally, the operator will take action as a result of an alarm indication, and only in special cases will he require the actual parameter measurement. Actual measurement values will most often provide assistance to maintenance personnel, and will be available to them as required.

An Amber and a Red threshold value are required for each parameter to be measured. These threshold values will be maintained in processor memory, since each measurement is compared with an established threshold crossing value. When a parameter measurement indicates that a threshold has been crossed, that measurement is stored for further use. The threshold values, stored in the processor, can be changed as required by authorized personnel. Such parameter changes will automatically be recorded on the Master Station Log.

2.1.5.2 Trend Analysis

Trend analysis will be performed for all measurements of a specific parameter once its value has crossed the Amber threshold. The trend is a basis for a prediction of when the Red threshold will be crossed. Trend predictions will be used to establish maintenance priorities, as well as to provide information required for a planned maintenance period. The information developed through trend analysis should be used to adjust the maintenance cycles to actual requirements.

As indicated, trend predictions will be performed by the processor analyzing the variations of the parameter level in the Amber range. A minimum of two threshold crossings are required to make the trend prediction. As long as each consecutive intermediate threshold crossing is approaching the Red threshold, the last two intermediate thresholds can be used to predict the time of failure. If the trend turns and the parameter value starts to return toward the initial Amber threshold value, a failure prediction cannot be made by using the last two thresholds. In the latter case the Amber threshold may be used as a reference point, so predictions can be made when the trend is an improvement.

2.1.5.3 Status Correlation and Analysis

Status correlation and analysis is the processor function which associates interacting sensor data to logically assess circuit, equipment and link problems in terms most useful and significant to the operators. In its simplest form, it is effected, as described earlier, in circuit fault location through correlation of measurements taken at various equipment appearances throughout the station, to determine whether a fault is located in the station, and if so in what equipment area. Fundamentally, a number of requirements have emanated from the combined equipment, link, circuit and system performance studies. A few of the more important requirements justifying the need for correlation and analysis of status information are:

- Reduction of operator confusion and fatigue
- Immediate availability of information delineating the extent of the outage; e.g., quantity, types of circuits affected by the failure, etc.
- Restoration priorities
- Retrieval capability of circuit and equipment information for subsequent restoral action

Examples of status correlation and analysis include recognition of the effect of group failures in terms of circuit alarms (downward correlation) and recognition of groups of circuit alarms (upward correlation) in terms of group equipment or link failures. In the more complicated problems, the importance of processor correlation is exemplified by the fact that the operators must, in each case, be provided alarm information at the cause rather than the symptom level.

While the larger scale correlative actions may be programmed in a modular fashion, the specifics for a given station will, to a large extent, be dependent upon the equipment configuration of a given station and the failure and degradation modes of that configuration.

Examples of correlative processing modules are those necessary to:

a. Evaluate circuit and channel failures in the event of LOS, tropo or HF link propagation problems.

b. Evaluate circuit and channel failures in the event of LOS or tropo link equipment problems.

c. Evaluate circuit and channel failures in the event of supergroup or group multiplex equipment problems.

d. Evaluate groups of channel or circuit problems in terms of group equipments which could be causative.

It should be noted that a, b and c produce somewhat similar symptoms of circuit and channel problems. One of the functions of the correlative processing will be not only to suppress the resultant circuit alarms, but to provide the operator with the correct cause of the overall problem.

From the foregoing, it can be seen that the processor must provide, to the operator, indications of problems in a known hierarchy. Circuit and channel problems constitute the basic level of precedence. The next higher level will be that of link problems. An indication of a link problem will be presented to the ATEC operator, by the processor, and will be followed by the circuits that will be, or are being, affected by the link problem. The highest level of indication will be that of equipment problems. Equipment problems may or may not affect link performance, depending upon just what equipment has failed or degraded in performance, but in most cases it will affect circuits. Therefore, the hierarchical precedence will have equipment failures or degraded performance indicated, by the processor, when they occur followed by link affected (if any) and circuits affected. An indication of link failure or performance degradation (without an equipment indication), such as noted above for link propagation problems, will be presented to the operator, by the processor, followed by the associated circuits that may be, or will be, affected. The operator can then concentrate on link restoration and any necessary rerouting that may be required, without concern for equipment substitution. The Amber or Red indication of circuit performance will be suppressed when there is an associated indication of equipment and/or link failure or degraded performance. The association between circuits, links and equipment must therefore be known, at all times, to the processor in order to present the point of the problem rather than the symptom.

2.2 Restoral and Rerouting

2.2.1 General

The restoration and rerouting functions are a natural continuation of the monitoring and testing functions described earlier. That is, the actions of restoring and rerouting generally result from detection of a degradation or failure by the monitoring and testing functions.

Accomplishment of restoral and rerouting is the result of the performance of numerous individual decisions and actions in an orderly sequence. Although this sequence may vary, depending upon the actual circumstances, it generally includes the majority of the following items performed in approximately the order indicated:

a. Recognition of degradation or failure and of need or desire to reroute

b. Validation of degradation or failure

c. Coordination relative to degradation or failure

d. Determination of capability for restoral or reroute

e. Accomplishment of restoral or reroute

f. Diagnosis of fault (localization and isolation)

g. Repair of failed or degraded "unit"

h. Verification of acceptability of repaired unit

i. Return to original configuration if required

Rerouting may also be accomplished for other purposes, such as (a) freeing a channel from service to permit out-of-service testing, (b) obtaining improved performance or another category of service on a tempory basis, and (c) establishing on-call or temporary circuits.

The ATEC system will provide an improved capability for the restoral of degraded or failed service. Where the degradation is in-station and is caused by a drift in some characteristic of an equipment, such as the gain of an amplifier, it will be possible, because of the trend analysis capability, to identify and to make a readjustment on an in-service basis without interrupting traffic. When service must be interrupted for restoration, ATEC will make recommendations regarding the use of spares or preemption of equipment normally providing a lower priority service.

Changes in interconnections will be facilitated by the use of automated patching facilities within the ATEC facility. Four types of patching will be provided:

- Group
- Circuit (i.e., equal level)
- DC
- Primary

After completion of restoral or rerouting, monitoring and testing will again be resumed in order to verify the restoral or reroute.

The general location of the fault, i.e., within the confines of the ATEC facility's jurisdiction or external to it, may be obvious or it may be obscure. It is the intent of the ATEC facility design to minimize this obscurity. Upon localization of the fault, restoral action must be initiated. However, such action can be undertaken by the ATEC facility operator only for cases where the fault is not of an external nature; otherwise, it is only logged and turned over to the appropriate facility.

Restoral action will generally consist on one of the following:

a. Substitute spare

b. Reroute

c. Preempt

d. Change RF frequency

e. Align or adjust

f. Condition or recondition

g. Repair

Only e. (Align or adjust) can be accomplished without service interruption. In general, the first four types of restoral action will normally be accomplished in accordance with certain pre-plans or SOP's. That is, certain spare channels and certain spare equipments are normally designated as spares for certain other operational channels and equipments (on a priority basis). Likewise, certain designated reroutes and preempts will be permissible, and certain designated HF frequencies will be available as alternates on a scheduled basis. All of the information regarding these specifics must be available in stored form for presentation (display) to the operator.

The approach, then, to accommodating the restoral and reroute functions within the ATEC facility is to provide status monitoring positions equipped with the "tools" required to facilitate these functions. A CRT display will provide access to preplanned restoral information and to information indicating usage or availability, as well as status of restoral facilities. In fact, even step-by-step procedures can be

displayed. As a separate entity, the required patching (manual) or switching (automated) must be provided, and must be controllable by console operators.

2.2.1.1 Automated Patching

Restoral actions which involve substituion of spare equipments or rerouting via spare channels or via preempting in-use channels of lower priority require the employment of patching and/or switching. Also, establishing on-call patches or emergency circuits, as well as rerouting for purposes other than restoral, require patching and/or switching. Referring to Figure 2, sheet 1, of Section IV, patching is generally provided at the points indicated. A primary consideration of ATEC was to automate this patching function or to implement semiautomatic (manually controlled) cordless patching. The advantages to be gained by such an approach include speed (reduction in patching time), accuracy (reduction in human error), improved performance (use of sealed switch contacts vs. exposed patch jack contacts, subject to contamination), and more efficient operation (fewer personnel required and more centralized operation). Still another advantage is the capability for automated record keeping of patching status. This advantage is inherent in a processor-controlled switching system.

2.2.1.2 Manual Patching

The aut..ated patching concepts considered above were found to be quite costly (equipment and space). An effective approach to automated patching must employ only a limited amount of switching, and must include manual patching to obtain the required flexibility and provide for total capacity. In addition, manual patching must be provided to afford emergency manual back-up in the event of failure of the automated switching.

The major shortcoming of the conventional manual patch panel has been its contribution to the degradation of circuit quality. That is, the many contacts (normal-through connections) that are present in a long-haul circuit become dirty, corroded or contaminated, and offer a large number of contact resistances, each serving as a separate noise generator. All of these noise generators, effectively connected in series, can contribute significantly to the total noise on a circuit. The solution to this problem is to provide patch panels with normal-through contacts sealed in a controlled atmosphere, i.e., sealed reed relay units. To satisfy this requirement, it is recommended that all existing patch panels be replaced with new patch panels that do not have any exposed or unprotected contacts within the communications signal path.

It is also recommended that these patch panels be designed so that automated patching can be added at any future data (see paragraph 3.2 of Section IV for additional detailes). This design should permit the connection of switching to the jack sets on an individual circuit basis (allowing selection of specific circuits to be

provided with switching), and should not interrupt or otherwise affect the circuits so connected. In line with this approach, it is recommended that an indicator lamp be associated with each jack set to provide an indication when that particular appearance is switched/patched. Such indicators are required for two reasons: first, they provide an indication to any operator that the appearance in question is in fact switched, thereby precluding attempted manual patching of that appearance; second, they provide a quick visual indication of the abnormal circuits, or switching, currently in effect. The latter use provides a "picture" of patching status.

Also in concert with the above approach is a requirement for patch cord scanning. That is, where a patch has been manually accomplished (via patch cord), it is necessary that the ATEC processor be made aware that such a patch actually exists. This information (identity of required patch) will be keyed into the processor by the operator accomplishing restoration via switching/patching. The processor must then scan the jack set to ensure that no patch already exists at that appearance, and must eventually verify (via repeated scanning) that the manual patch was installed, and that it was installed as directed. Hence, manual patching operator errors will be detected. A similar function must be provided for patches that were accomplished via switching action under processor control. However, here the instruction will be keyed into the processor and, upon switching verification, will be recorded until the patch is removed by another switching action. It should be noted that a specific requirement of the switching subsystem is a verifification signal from the switch that the addressed connection has actually been accomplished. The combination of processor record keeping and patch cord scanning will provide the above required capabilities; it will also provide the capability of reading out the real-time patching status to both the CRT display and the page printer, upon operator request.

2.3 Quality Control

Another function in the ATEC system will be quality control. This function will perform frequent quality checks on spare channels, circuits, links and equipment to confirm their availability for substitute use. It will also, on a regularly scheduled basis, perform detailed out-of-service tests on each active channel, circuit, link and equipment. The function will also perform acceptance testing of new and repaired equipment, and also of circuits ready for activation, prior to their incorporation into the active communication system.

The quality control function involves the performance of tests in an orderly manner and in accordance with some schedule or some more immediate need, e.g., in support of status monitoring relative to isolation of a particular fault. With the aid of test procedures and test equipments, the quality control function must perform the following set of actions: (a) access of the circuit or equipment to be tested and connection of the test equipment as required, (b) performance of measurements in accordance with the test procedure, (c) orderly collection of results of these measurements, (d) association, analysis and evaluation of these results, (e)

presentation of results, (f) acquisition of additional relevant data, if required, (g) decisions based upon these results and data, and (h) initiation of action as a result of these decisions. Items (c) through (h) are found to be identical with items (c) through (h) for Fault Detection and Isolation (subparagraph 2.1). Hence, these two areas (fault detection and quality control) are similar with respect to the action required and capability provided.

2.4 Record Keeping and Reporting

The ATEC will provide automation for record keeping and reporting. Each significant event in an ATEC facility will be recorded in an activities log as a chronological printout, and will be entered into a magnetic tape unit to form a historical record which can be used for subsequent analysis. Information relating to an event may enter the data processor as a result of routine monitoring of circuits, equipments and links through automated fault isolation, or by manual entry by an ATEC facility controller. The historical data can be extracted by the controller for on-site analysis of recent (such as same day) problems and trends; mainly, however, the magnetic tape reels will be forwarded to a central location for detailed analysis by an off-line data processor.

The ATEC facility processor will use the status data which is constantly being entered into it to compose automatically as much as possible of the formatted portions of reports to O&M agency and DCA Operations Control Complex (DOCC) elements immediately superior to the ATEC facility. Just prior to the scheduled transmission time for either type of report, the processor will present the report on a CRT for review, editing, revision and entry of data which is not available in the processing subsystem. Upon release by the operator, the report will be automatically transmitted from the ATEC facility. These reports will contain information on any other sites for which the ATEC facility has reporting responsibility, derived from inputs supplied by these other sites.

The ATEC facility processor will maintain, in its dynamic data base, information of the type which is normally recorded manually into various records and forms by Technical Controllers. The forms of particular interest, as listed in Volume 2, Chapter 11, of DCAC 310-70-1 are:

- Trouble and Restoration Record (DD Form 1443)
- Analysis of Channel Operation Form (DD Form 1440)
- Wideband Outage Record (DD Form 1698)
- Technical Control Communications Work Order (DD Form 1445)
- Record of Frequency Changes (DD Form 1444)
- Conference Record (DD Form 1442)
- Trunk Channelization Record (DD Form 1699)
- Master Clock Log (DD Form 1700)

By extracting pertinent information from the data base, the processor can produce a printout of the equivalent (if not an exact duplicate) of any of these forms, either on schedule or on operator request.

Record keeping is a basic function required to be performed in any separate operational entity where personnel, equipments or services are involved. Records of activities, indications of personnel and equipment performance, and the services provided are required by supervisors as well as higher-level management. These records consist chiefly of the basic information used in the performance of functions and tasks necessary to the mission; they are not items of information that must be purposefully obtained by personnel for reports only. The generation of formal reports is merely the compilation of static data base and dynamic status information which has been previously stored in the processing subsystem, and an automatic request and acceptance of information from a Central Control position for items not available in storage.

2.4.1 Record Keeping

Record keeping in a Technical Control facility of the DCS is a basic function which is considered mandatory. The record information concers: (a) dynamic communication configurations, (b) current status of equipments and communications service, (c) communication performance as related to immediate trends, (d) possible actions to include preplanned reroutes, and (e) related corrective action and support information. This basic information is necessary to the Technical Control operator in order to make the appropriate decisions. In the ATEC facility, it is the intent to automate record keeping functions. It must be realized that the record keeping function for an ATEC facility cannot be completely automated so long as humans are involved in the monitoring evaluations and in the actions to be taken. Technical Control operators will be required to provide supplemental information and changes, and in some cases originate complete records.

The record keeping function of an ATEC facility concerns the following major categories of information, with possible breakdowns for processing purposes as indicated:

- Static Data Base

  Configuration listings with identifications (DCS Directory and similar non-DCS listings) for:

  - User circuits (segment-by-segment, through facilitites, end-to-end, send and receive)

  - Preplanned reroutes (segment-by-segment, through facilities, end-to-end, send and receive)

- Through circuits (segment-by-segment, through facilities for: local station responsibility, region, area or end-to-end, as appropriate)

- Trunks (send and receive)

  Channels (send and receive)

- Links (send and receive)

  Supergroups (send and receive)

  Groups (send and receive)

  Channels (send and receive)

- Stations (connectivity)*

- Equipments (connectivity)*

Detailed technical information on each circuit (equipment type, bandwidth, conditioning, standard or normal noise and signal levels and phase delay)

Station frequency directory

- Dynamic Data Base

Identifications plus dynamic status postings and other transactions to include loading, maintenance condition, etc., of:

- Communications (DCS and non-DCS identifications)

  User circuits (direct responsibility)

    Sensor #1 (parameter identification and value ranges for Green, Amber, and Red conditions)

    Sensor #2, etc.

  Through circuits

  Sensor #1 (parameter identification and value ranges for Green, Amber and Red conditions)

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* NOTE: Connectivity data will also be dynamic in the sense that it will change on a temporary basis as a result of patching and switching actions.

Sensor #2, etc.

Trunks

Channels

Sensors

Links

Supergroups

Sensors

Groups

Sensors

Channels

Sensors

- Equipments (nomenclature)

  Sensor #1 (parameter identification and value ranges for Green, Amber and Red conditions)

  Sensor #2, etc.

- Connectivity

Unplanned rerouted (configuration used) listings

In addition to the static and dynamic data base information involved in record keeping by the processing subsystem, some printouts will include items of information presently maintained manually by Technical Control personnel on designated logs and forms. These logs and forms are described in Volume 2, Chapter 11, of DCAC 310-70-1. The presently used manual logs and forms as required by DCAC 310-70-1 are:

- Master Station Log
- Trouble and Restoration Record (DD Form 1443)

- Analysis of Channel Operation Form (DD Form 1440)
- Wideband Outage Record (DD Form 1698)
- Technical Control Communications Work Order (DD Form 1445)
- Record of Frequency Changes (DD Form 1444)
- Conference Record (DD Form 1442)
- Circuit Data (DD Form 1441)
- Trunk Layout Record (TLR) (DCA Form 155)
- Circuit Layout Record (CLR) (DCA Form 139)
- Trunk Channelization Record (DD Form 1699)
- Master Clock Log (DD Form 1700)

Much of the same information as presently maintained manually on the above-listed logs and forms will be included in the data base of the processing subsystem. Communication status and related semiautomatic Technical Control actions are to be posted (in most cases automatically, and in other cases semiautomatically) against identifications of communications and equipments in the data base of the processing subsystem. Therefore, the equivalent information of the Trouble and Restoration Record (DD Form 1443) will be kept internal to the processing subsystem for "open" events. As a result, the Trouble and Restoration Record (DD Form 1443) equivalent can be printed out automatically when each outage event is "closed", or partial displays/printouts of this record can be made upon request of the operator prior to "close-out" of reportable and nonreportable events. These printouts of the Trouble and Restoration Record (DD Form 1443) equivalent can be used by Technical Control personnel to make up a file of events for the station, for each radio day, for manual analysis purposes. If the equivalent of the Analysis of Channel Operation Form (DD Form 1440) is required of the processing subsystem, it must maintain a cumulative record of all outages, reasons for outages, and related actions taken for a 24 hour period of time.

The Wideband Outage Record (DD Form 1698) may be used in lieu of the Trouble and Restoration Record at wideband locations. For record keeping purposes no distinction is made herein.

Any form equivalents initially produced by the processing subsystem which require operator inputs are to be displayed on the CRT at the appropriate operating position. The outputs of these forms will be queued in relative priority with other information for the operator's attention. The operator at that position can then enter information into the form and re-enter the complete or partial information, as appropriate, into the processing subsystem for printout of the completed form.

Activities logs will have to be maintained at each Technical Control operating position. The activities log for the Central Control position will be termed the Master Station Log. It is expected that the Master Station Log will contain the significant items of information also contained in each of the other operating positions' logs, as well as other entries made by the Central Technical Controller. Entries into the activities logs, including the Master Station Log. will be made by the processing subsystem and by the individual operators. Entries made manually by operators are to be simultaneously entered into the processing subsystem as well as into the activities logs. In this way the processing subsystem can update the Master Station Log.

The Technical Control Communications Work Order (DD Form 1445) equivalent is to be initiated by the processing subsystem each time a fault is automatically isolated to equipments at the central station or remote sites under the central station's responsibility. The operator can initiate the display of this form's equivalent for conditions known to the operator through testing, or other means, and not isolated as a result of the automatic monitoring function in the processing subsystem. After display, he can enter the required information via his CRT associated keyboard. He can also enter information into the form when it is initiated by the processing subsystem. This display/printout of the form is for use in notifying maintenance personnel of failure of substandard operation of equipment. It also provides a record of equipment status for the Technical Controller. Completion of the form requires information from maintenance personnel; such information must be entered into the form manually, and, if it reflects the status of communications, it must also be entered into the processing subsystem for posting.

The Record of Frequency Changes (DD Form 1444) can be automatically produced by the processing subsystem from postings of frequency changes against trunk/link identifications in the data base. For this purpose, it is desirable that communication entities which require frequency changes in their operation be grouped in the data base, or otherwise associated. Entries of status regarding frequencies in use and frequency changes must be manually made. Therefore, the diaplay of this form on the CRT at the operating position for a particular communication entity can be ordered by the operator. He then enters the appropriate frequency change information, primary and secondary frequencies in use, etc., into the form for status update and/or for printout of the completed form.

The Conference Record (DD Form 1442) is normally used by Technical Control operators to provide a record of all on-call patches, radiotelephone conference and teletypewriter conferences. In the ATEC facility, the operator can "instruct" the processing subsystem to display this blank form on the position CRT when he has a need for it. Upon presentation of the form on the CRT (same arrangement as DD Form 1442), the operator can enter the appropriate initial information and further "instruct" the processing subsystem to store it for later retrieval. This information is used by the processing subsystem for activities log entries. Upon completion of the on-call patch or conference, the operator can recall this form partially completed, for total completion and printout as required.

The Circuit Data (DD Form 1441), the Trunk Layout Record (DCA Form 155) and the Circuit Layout Record (DCA Form 139) can be stored in slide form, recalled, and viewed by operators at the static reference facility associated with operating positions. This facility is totally controlled by the operator, and has no direct connection with the processing subsystem. The static reference facility produces a projection of information from photographic slides.

The Trunk Channelization Record (DD Form 1699) information will be stored in the processing subsystem as part of the static data base. This information can be ordered in a presentation on the CRT or in a printout by operators. Similar information may be included in the static data base relative to assigned frequencies for paths of the trunks and links for the station. However, such information for the station may be considered as classified. Therefore, the frequencies authorized may have to be stored in the processing subsystem and in coded form. If stored in the processing subsystem, such information can be recalled by the operator for his needs.

A record of clock accuracies can be maintained by the processing subsystem when automatic controls to such clocks are provided. The Master Clock Log (DD Form 1700) is currently used at those TCF's that are responsible for maintaining the accuracy of the master or station clocks. The form is normally maintained manually. Completion of DD Form 1700 includes: (a) date-time checked, (b) seconds fast-seconds slow, (c) corrected, yes or no, and (d) operator's initials.

2.4.2 Reporting

The semiautomatic generation of formal reports as required in conjunction with the Central Control position is a role of the processing subsystem. It is feasible to satisfy the formal reporting requirements in future ATEC facilities without significant additional burdens on the processing subsystem. The generation of formal reports is merely the compilation of static data base and status information previously stored, and automatic request and acceptance of information from the

Central Control position for items not available in storage. Consideration of the reporting requirements, however, is required in the design of the processing programmed software so that it can accommodate and perform the required reporting in the most effective manner in consideration of the processing functions as a whole.

A semiautomatic reporting capability is to be provided for reports required by DCAC 310-55-1 and AFCSR 100-17 (O&M organization requirements). This reporting capability will permit changes, additions and deletions by the Central Controller, and approval/release pr) transmission of the report to the local O&M Management Center (or elsewhere). The initial generation of a report includes display of the report information on a CRT at the Central Control position for modification and release as necessary.

As an element of a DCS station, the ATEC facility must be responsive to the needs of the DOCC. These needs will reach the ATEC facility as Circuit Engineering Orders (CEO's) or as ODM's. Upon completion of the required action, the ATEC facility will notify the DOCC element of such completion or of the inability to fulfill the requirement. Furthermore, the ATEC facility must submit near-real-time and periodic status reports concerning transmission links, supergroups, groups, channels and circuits. These reports (ODR's) are prepared in accordance with DCAC 310-55-1. It is recommended that the ATEC facility report on all DCS stations within its zone of responsibility.

The ATEC facility bears a similar relationship to its O&M agency in that it receives instructions and requests for information from the appropriate O&M element and submits reports to the O&M element. It also requests assistance of either DOCC or O&M element, as appropriate.

At present, the reporting requirements of the three military departments are similar, but not identical. Hence, a different report preparation routine will be needed in each ATEC facility, depending on the O&M agency. It will be advantageous in the ATEC system if a single reporting doctrine is used by all three O&M agencies. Not only can one program routine suffice at all ATEC facilities, but each ATEC facility can prepare a single, consolidated report for all stations in its zone and forward this report to all O&M agencies represented in the zone. This will reduce the reporting load on the manual sites by having the ATEC data processor handle much of the effort.

As a further step toward reduction of the reporting load and standardization of reporting, it is recommended that one report serving the needs of the DOCC and the O&M agencies be prepared and submitted to all elements. This report can retain the format specified by DCAC 310-55-1 and can satisfy the needs of O&M agencies through the use of narrative text permitted by DCAC 310-55-1. A single format should be used to meet everyone's requirements to obtain ever greater standardization.

3. INTERRELATIONSHIPS OF ATEC

It is visualized that the incorporation of the ATEC into the DCS will be limited by economic considerations to only a portion of the DCS stations. In this case the logical choices for implementation are those TCF's which lie at major points where there are intersections of three or more major links in which the main line route of communication within the network are carried. By virtue of the ability of the ATEC to "see" problems in a large portion of the network surround it, significant assistance in fault detection can be provided to manual TCF's in a large geographical region, which can materially reduce outages and improve user service. This "visibility region" of ATEC facilities should be adjoining so that coordination on fault detection between ATEC's will have no blind spots.

The ATEC will be of benefit to its entire "area" in functions other than fault detection:

a. By serving as a data collection point for the region and by exploiting its reporting capabilities, serving as the DCS reporting station for the region.

b. By serving as the central coordinating station for a region in resolving inter-region problems with adjacent ATEC's.

3.1 ATEC Interfaces

In carrying out its functions, the ATEC facility must interface with the various elements of the DCS which contribute to provision and maintenance of user service, with the DOCC and with the O&M agency.

3.1.1 Interfaces With Other ATEC Facilities

The performance monitoring in an ATEC facility reveals problems in transmission links, in supergroups, in groups and in individual circuits. As each ATEC facility detects a fault in one of these categories, it must notify each adjacent ATEC facility which is affected by the problem so that these other ATEC facilities need not waste time on investigating a fault which lies outside their areas of capability.

The coordination communications required to accomplish this function can be automated to require minimum or no operator attention. Inter-ATEC communications can readily be interpreted by the processors at each station to provide discrimination in interpretation between "action" and "advisory" data. It is also feasible to automate requests for assistance between ATEC facilities, such as application of test signals to a channel. In summary, most of the inter-ATEC coordination can be accomplished between facilities on either a wholly automatic basis or with minimum operator intervention.

3.1.2 Interfaces With Manual TCF's

The ATEC facility will coordinate with TCF's in circuit activation, deactivation and rearrangement; in testing and alignment; and in restorals. It will call for assistance and will offer assistance, as required.

As a DCS reporting station, the ATEC facility will receive status reports from the TCF's in its zone for inclusion in the reports to the DOCC element.

3.1.3 Interfaces With Remote Radio Terminals

The ATEC facility will be responsible for technical direction of activities at the remote sites, and will assist in the resolution of difficulties. Alignment and testing of the inter-site link will be a joint effort.

The ATEC facility will report on the remote sites in its reports to the DOCC element.

3.1.4 Interfaces With Commercial Carriers

If an ATEC facility detects a fault which is suspected to lie in the facilities provided by a commercial carrier, it will notify the carrier of the problem and, to the extent necessary, work with the carrier in the isolation of the fault. The ATEC facility will similarly be advised by the carrier of problems detected by the carrier which affect circuits appearing in the ATEC facility. The two organizations will also coordinate on circuit activation and testing and on the establishment of reroutes.

3.1.5 Interfaces With Users

The ATEC facility is responsible for maintaining acceptable service to its directly connected users and, therefore, controls the restoration of service to these users. Certain major users, like AUTOVON and AUTODIN switching centers, have built-in capabilities for the detection of circuit problems. For example, AUTOVON performs tests on idle inter-switch trunks with a trunk routiner. When troubles on trunks are detected, the routiner should generate an output to the ATEC facility, identifying the defective trunk. Similarly, AUTODIN performs certain error checks on incoming messages on both user circuits and inter-switch trunks. Here, too, the identity of circuits or trunks passing through the ATEC facility and showing unduly high error rates should be sent to the ATEC facility so that corrective actions can be taken.

In a similar manner, significant outages detected by the ATEC facility will be passed to AUTOVON and AUTODIN so that trunks can be busied out or traffic throttled until the trouble is cleared.

The ATEC facility will have to work closely with the PTF's at user locations for the isolation of problems on the user loop and in the user terminal. It will also need the cooperation of the user in end-to-end testing of the entire circuit or of the user loop. In some cases loopback is needed at the user site, and in other cases, at the ATEC facility.

With terminal-type users and manual switchboards, automatic transfers of information to the ATEC facility may not be feasible or warranted economically. In these cases manual communication is called for and will be perfectly adequate. The user will call in problems to the ATEC facility and, in turn, it will notify the user of any difficulties it has uncovered.

3.1.6 Interfaces With DOCC and O&M Agency

As an element of a DCS station, the ATEC facility must be responsible to the needs of the DOCC. These needs will reach the ATEC facility as Circuit Engineering Orders (CEO's) or as ODM's. Upon completion of the required action, the ATEC facility will notify the DOCC element of such completion or of the inability to fulfill the requirement. Furthermore, the ATEC facility must submit near-real-time and periodic status reports concerning transmission links, supergroups, groups, channels and circuits. These reports (ODR's) are prepared in accordance with DCAC 310-55-1. As stated earlier, it is recommended that the ATEC facility report on all DCS stations within its zone of responsibility.

The ATEC facility bears a similar relationship to its O&M agency, in that it receives instructions and requests for information from the appropriate O&M element and submits reports to the O&M element. It also requests assistance of either DOCC or O&M element, as appropriate.

SECTION IV

ATEC FACILITY DEVELOPMENT AND DESIGN

1. DESCRIPTION OF ATEC FACILITY

The following paragraphs present an overall description of the recommended ATEC facility and of its associated remote radio terminal sites and repeater sites. This description shows the relationship existing between the communications system elements and the ATEC system elements, and between ATEC system elements, at the DCS station.

1.1 Communications Elements

Sheet 1 of Figure 2 shows the communications elements which are typically found in an ATEC facility except for the items in heavy outlines, which denote ATEC elements. Included in the category of communications elements are;

a. Tropospheric scatter terminals

b. Microwave line-of-sight terminals

c. Land line cables to HF radio sites and users

d. Frequency division multiplex (FDM)

e. Time division multiplex (TDM)

f. Line conditioning equipment for VF channels

g. VFCT's

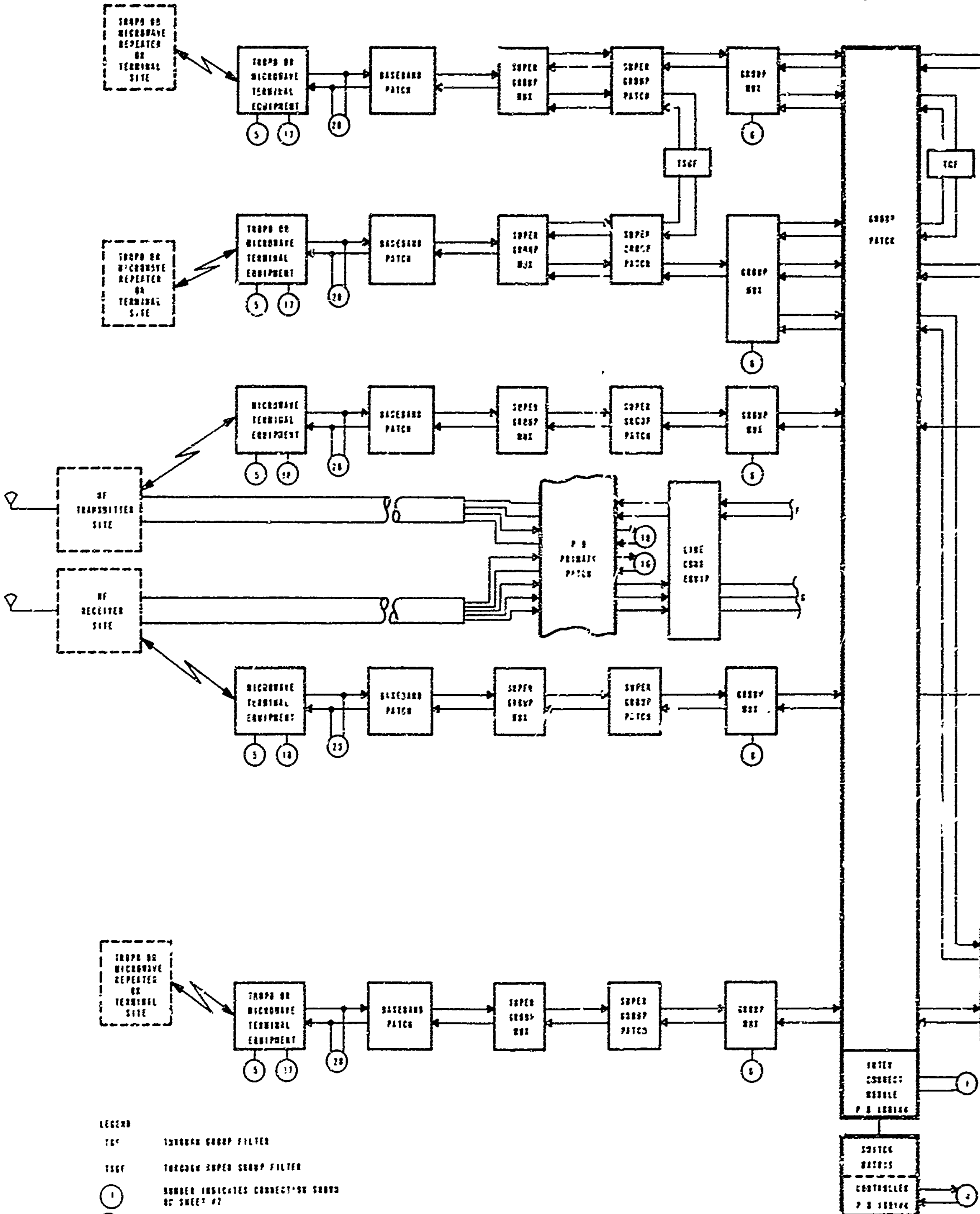
h. Radio telephone terminals

i. Data modems for digital signals

While the diagram shows that for TDM the composite digital signal may be transferred into and out of the ATEC facility via a group modem or a carrier cable, it is also possible to use supergroup modems or to transmit the high data rate over a separate microwave link, as to a satellite earth terminal.

1.2 Patching

The principal ATEC elements shown on Sheet 1 of Figure 2 are the ATEC patching elements enclosed in the heavy outlines. It is recommended that the following new patch bays be provided:



LEGEND

TGF — THROUGH GROUP FILTER

TSGF — THROUGH SUPER GROUP FILTER

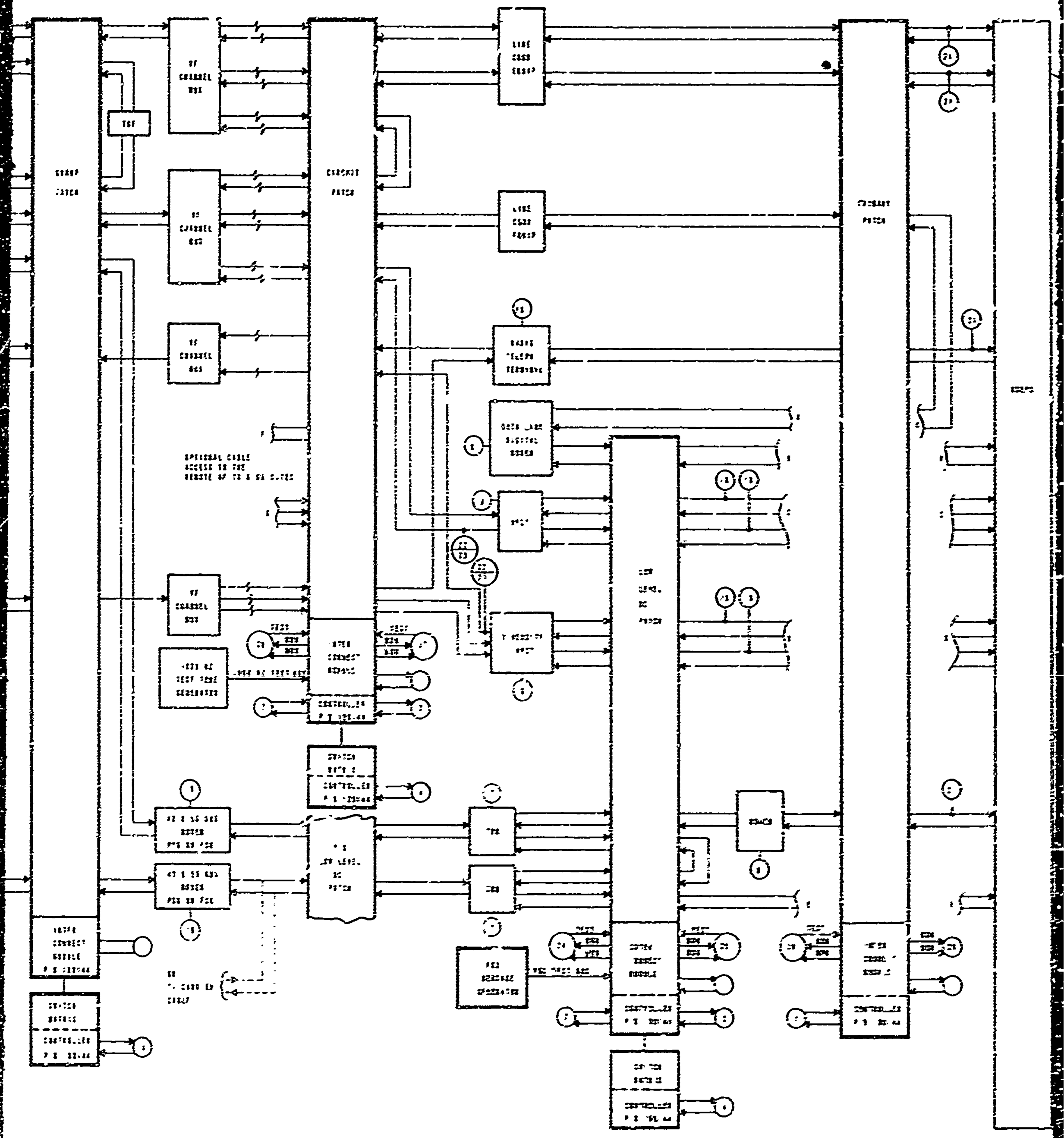
(1) — NUMBER INDICATES CONNECTION SHOWN ON SHEET #2

(1/2) — EITHER NUMBER IS APPLICABLE (BUT NOT BOTH)

| — THICK SOLID LINES INDICATE NEW OR EXTENSIVELY MODIFIED EXISTING COMMUNICATIONS EQUIPMENTS

– – – — REMOTE SITE

(XXXX) — CEI NUMBER



B

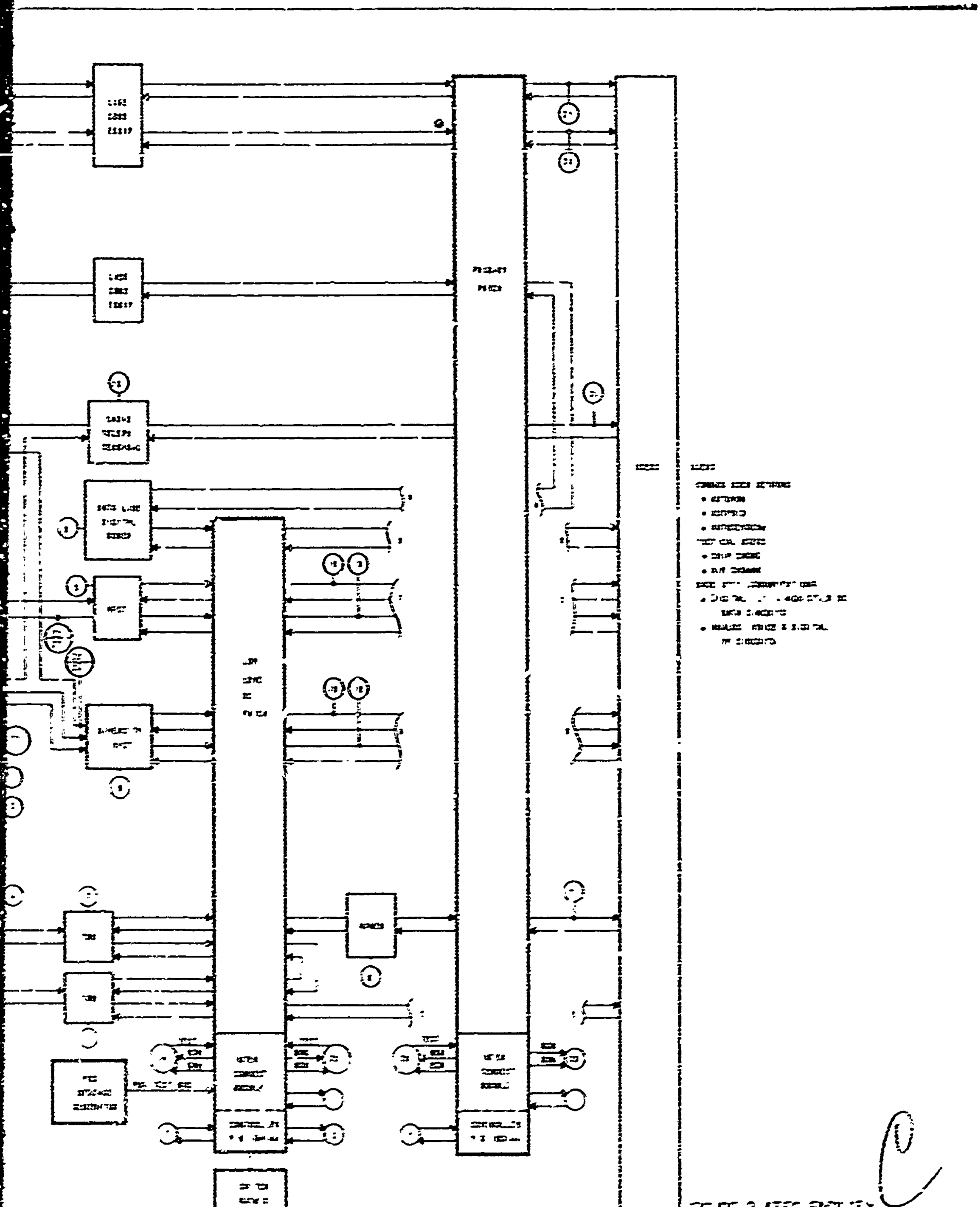


FIGURE 2 ATEC FACILITY
TECH CONTROL
EQUIPMENT
SHEET 1 OF 3)

a. For VF circuits, the customary three patch bays (VF, circuit or equal level, and cable) will be replaced by two new bays (circuit and primary). The new bays will contain jacks to equip 24 full-duplex circuits in one panel across the width of a 19-inch rack, and will use sealed reed relays in place of exposed-contact normal-through connections to eliminate contact noise. These bays will also contain semiautomatically controlled test and monitor trunks to the operating consoles to permit access to individual circuits or channels on a terminating or high-impedance bridging basis. One of the test buses in the circuit patch will permit the insertion of a 1000 Hz standard test tone into many circuits or channels simultaneously. This new patching arrangement will require that all line conditioning equipments (such as SF units, amplifiers, equalizers, echo suppressors, hybrids, and signaling converters) be grouped between the circuit and primary patches.

b. For DC circuits, a new DC patch bay will be provided. The features of the DC patch will be similar to those of the circuit and primary patch, and will include Fox generator distribution buses.

c. For group patching, a new group patch bay will be installed, which will (as above) also incorporate reed relays in place of exposed normal-through contacts. Because of the higher frequencies appearing in the patch bay and the greater risk of degrading the group signals, no test or monitoring trunks to operating consoles are provided; jacks will be used instead.

d. For supergroup and baseband patching, it is recommended that no changes be made because of the relative infrequency of such patching.

e. Each of the four types of patch bays described above contains an interconnect module and controller, which performs several functions. First, it provides a cord scanning function to verify that a patch cord has been inserted into or removed from the proper pair of jacks when manual patching is used. This cord scanning is directed by the data processor. Second, it provides for connection and disconnection of the monitor and test buses under processor control. Third, there is the connection and disconnection of the switch matrix to and from the points being switched, and the associated opening and closing, respectively, of the normal through relay path.

In addition to the improved, more versatile patch bays, several switch matrices are provided to permit the use of automated patching in lieu of cord patching. Three matrices are shown, one each for group switching, circuit (equal-level) switching, and DC (low-level) switching. Operations of the crosspoints in the matrices are under the control of the data processor in response to manually entered instructions. When a matrix-switched connection is established, indicator lamps at the corresponding jacks in the patch bay are illuminated to forestall inadvertent insertion of a patch cord into a circuit already switched by the matrix.

The switching matrix is designed to provide a limited number of simultaneous connections in order to minimize size and cost. The limit is on the order of 10 to 15 percent of the total number of normal through connections. Once the capacity of the matrix is exceeded (which should happen infrequently), overflow can be handled by manual patching. Manual patching also provides backup in the event of matrix inoperability.

The primary patch is intended to be used for substitution of line conditioning equipment. Since the frequency of failure of such equipment is quite low, it is recommended that equipment substitution be performed by manual patching at the primary patch. Accordingly, no primary switch matrix is furnished for automated equipment substitution.

1.3 Equipment and Link Sensors

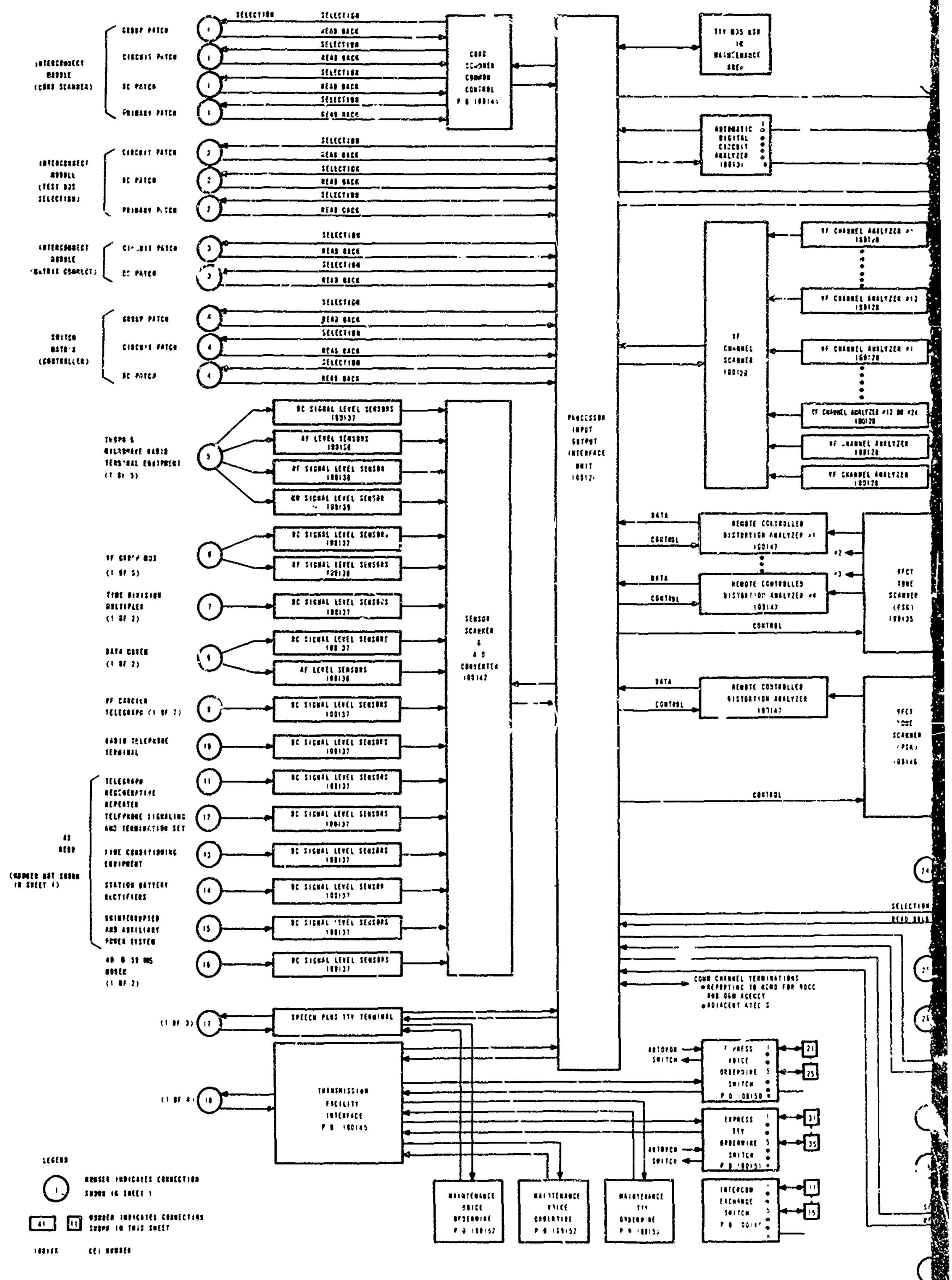
On Sheet 2 of Figure 2, circled numbers 5 through 16 indicate the connections of equipment and link sensors to correspondingly numbered points on Sheet 1. These sensors measure either signal characteristics or equipment performance characteristics, and develop DC voltage outputs in a standard range. The output of each sensor is sampled by a sensor scanner approximately once in two minutes, and is converted to a 6-bit digital code by an analog-to-digital (A/D) converter for transfer to the data processor. Four different types of sensors are used, covering DC, AF, RF, and MW ranges of sensed parameters.

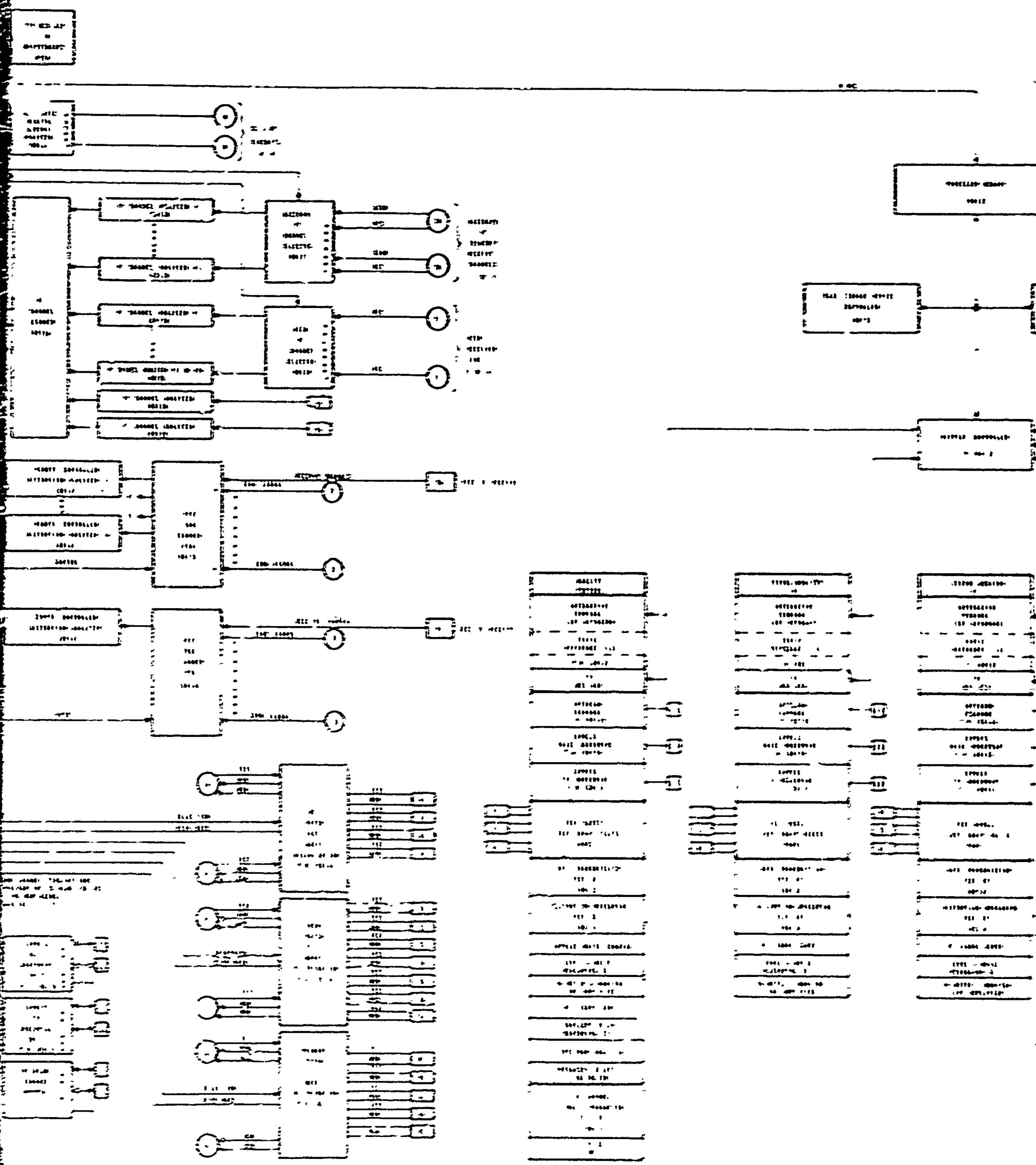
Additional inputs to the processor are derived from equipment and link sensors at remote radio terminals and repeaters, and are transferred to the ATEC facility via either the telemetry subsystem or the transmission facility interface. Later discussions of Sheet 3 of Figure 2 will provide additional details.

1.4 DC Circuit Monitoring and Fault Isolation

The outgoing signal to each user DC receive line is sampled about once every two minutes, and is analyzed for distortion and loss of transitions by an automatic digital circuit analyzer. The result of this analysis is passed on to the data processor.

A second form of DC circuit performance assessment is performed by a VFCT tone scanner and remote controlled distortion analyzer. The scanner accesses the VF transmit output of each VFCT, selects a tone channel and demodulates it to DC, and then measures distortion and detects loss of transitions. After each tone channel in a VF channel has been analyzed, another VFCT VF output channel is selected. Several tone channels may be analyzed simultaneously in order to maintain a scan cycle of approximately two minutes for each DC circuit. The characteristics of the VFCT tone scanner must match those of the VFCT's used, in terms of tone frequencies, frequency shift keying or phase shift keying (FSK or PSK).


SELECTION
READ BACK
CONTROL
DATA
LEGEND



B

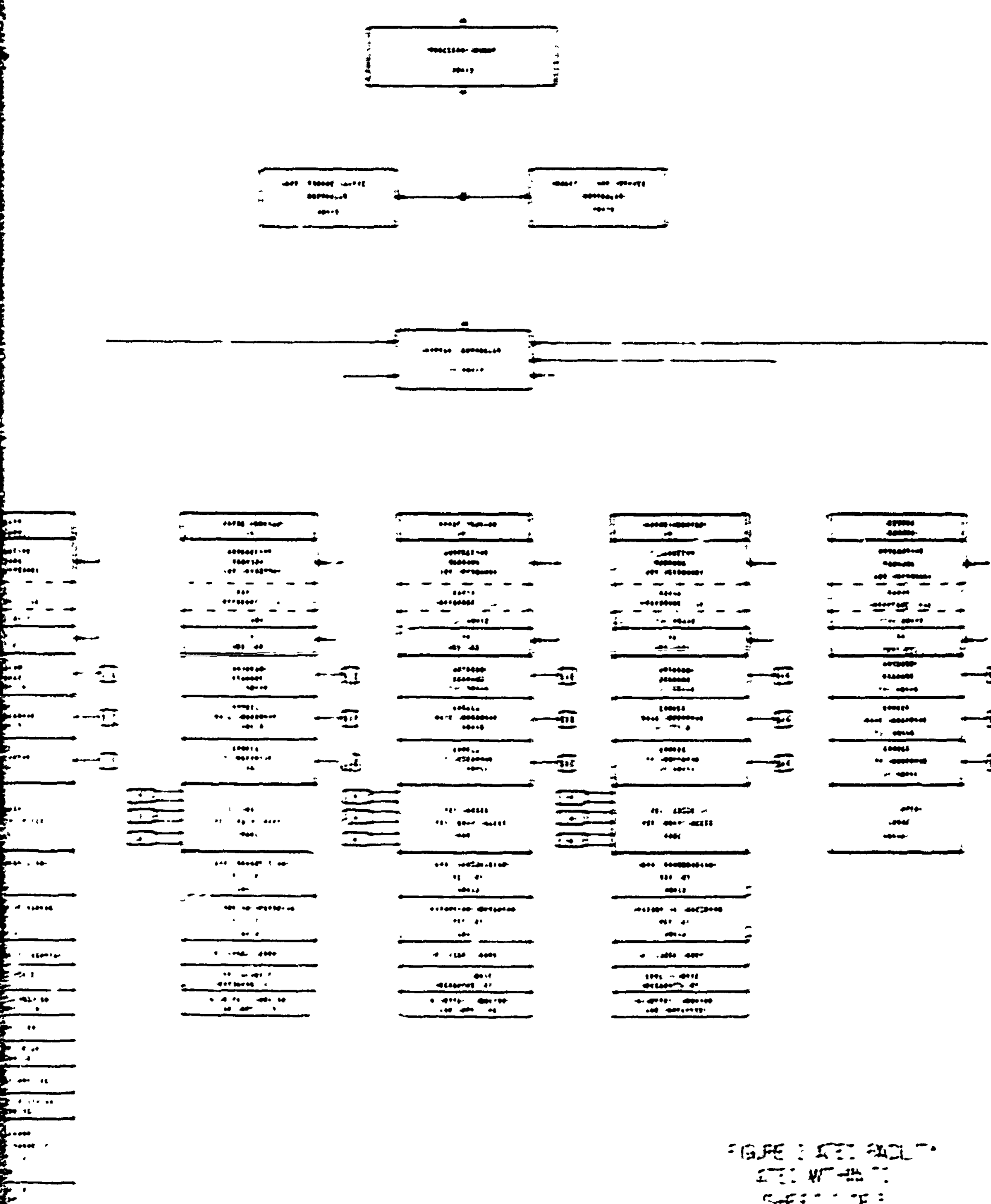
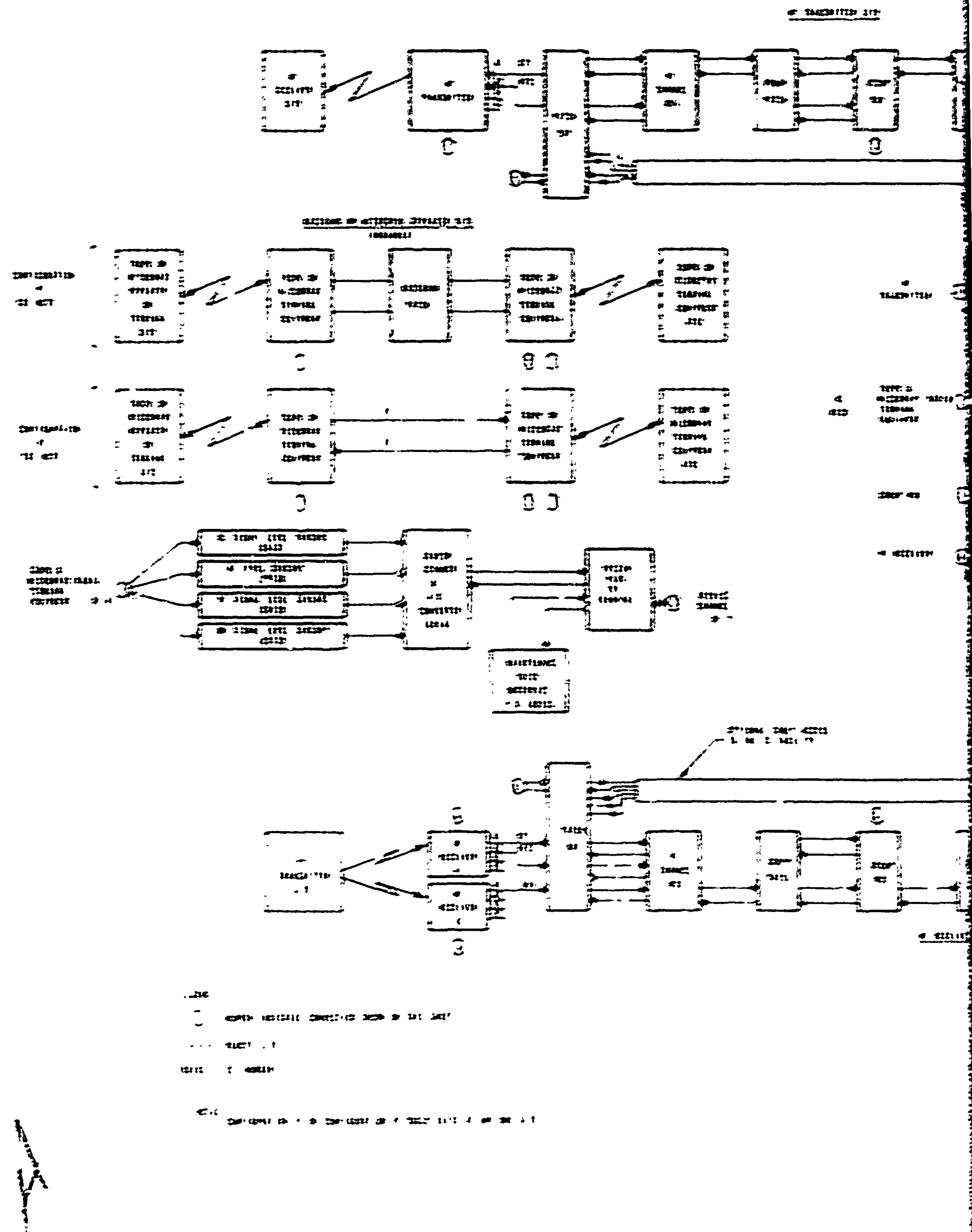


FIGURE [illegible] FACILITY
[illegible]
SHEET [illegible] OF [illegible]



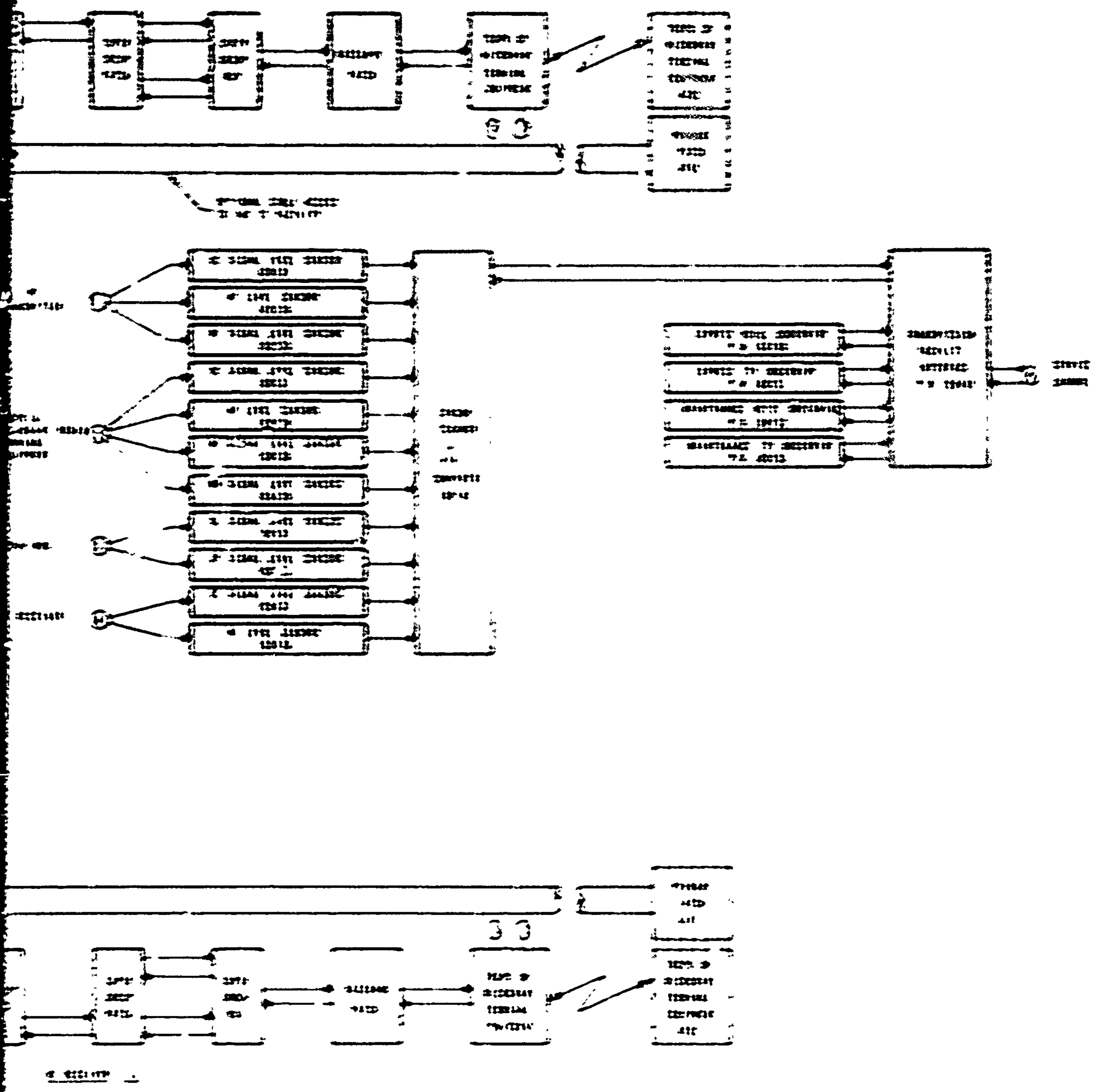


FIGURE [illegible] FACILITY
HF TRANSMITTER & RECEIVER
FRONT END REPLACEMENT SYSTEM
SHEET [illegible] OF [illegible]

Additional observations are made for fault isolation. When a faulty signal on a user DC monitor line is detected, the appropriate VFCT tone sender is connected to the VF monitor input of the VFCT to evaluate the quality of the tone channel, thus indicating whether the fault lies in the VFCT or elsewhere. Similarly, a tone channel at the VF output of a VFCT shows a fault, the input DC signal from the user line is monitored (via a DC patch monitor trunk) by a distortion analyzer test set in an operating console.

1.3 VF Circuit Monitoring and Fault Isolation

The VF signal entering each user VF receive line is selected by the user VF channel selector, and is analyzed by a VF channel analyzer. Up to 24 VF channels can be selected and analyzed simultaneously to permit a two-minute scan cycle for each channel.

At the transmit baseband of each frequency division multiplex system, the baseband VF channel selector selects one group at a time and delivers the outputs of the 12 VF channels to 12 VF channel analyzers for simultaneous analysis.

With a faulty user VF receive signal, the baseband VF channel selector is connected to the receive multiplex baseband, and the appropriate VF channel is selected and analyzed to determine whether the fault is internal or external to the [illegible] facility. With a faulty VF channel in the transmit multiplex baseband, a VF channel analyzer is connected via a monitor trunk at the primary patch to the corresponding user VF transmit channel for internal versus external isolation. Should either of the two foregoing fault isolation steps reveal an internal fault, a VF channel analyzer is connected via a monitor trunk of the circuit patch to the faulty channel, thereby determining whether the line conditioning or multiplex equipment is at fault.

1.4 Test and Monitor Bus Distribution

The test and monitor trunks or buses in the various patch bays are brought to distribution units, from which connections are made (a) to the operating consoles to which the buses are assigned and (b) to the circuit monitoring equipment used for fault isolation measurements. Changes in assignments of consoles can be implemented readily through the distribution units.

1.5 Operating Consoles

Operating consoles are provided for three separate functions. The first function is quality control, its primary responsibilities being equipment acceptance testing, acceptance testing of new circuits. Routine testing of circuits and equipment, both source and [illegible] fault isolation tests are also performed. This console is equipped with a cathode ray tube display, a keyboard for entry of [illegible].

a slide-projector-based static reference file, a teletypewriter for hard copy printout and for backup to the CRT and keyboard, a complement of test equipment for use on the patch bay test buses, and communications access through internal communications and voice and telegraph orderwires.

The second function requiring a console is status monitoring. All alarms generated by link, equipment, and circuit monitoring and fault isolation are displayed here on a CRT display. Through a keyboard, additional details on the fault, as well as data base information (on equipment, channels, circuits, trunks, groups, supergroups and links) can be obtained from the data processor or static reference file. When circuit restoration by rerouting is required, preplanned reroutes can be extracted from storage by keyboard request and used to determine what automated patching must be initiated via the console. The operator enters instructions to the data processor through the keyboard. Test equipment is available for monitoring and testing. Internal and external communications are supplied, thus permitting coordination with others for fault localization and correction. Hard copy printout is available on a teletypewriter.

Several status monitoring consoles are provided in larger facilities, so that the work load can be distributed among several operators when necessary.

The third function requiring a console is Central Control/System Performance. This console will service both the supervisory function of Central Control and the analysis function of System Performance monitoring. The latter function will require maintaining cognizance of the status of the communications system in the zone of responsibility of the ATEC facility, and will also require development of the details of unplanned reroutes. The Central Control function will be concerned with supervising the activities of the other operating personnel, coordinating with maintenance, other TCF's and ATECF's, DCOC element, and O&M agency elements, and users, as needed. It will also be responsible for the preparation, review and release of reports to DCOC and O&M agency. This console is equipped with CRT, keyboard, static reference file, hard copy teletypewriter, and communications, which makes it similar to the other consoles. It also has a high-speed line printer for the rapid printout of high-volume data, such as current alarm status, current patching configuration, etc.

With similar capabilities with respect to CRT, keyboard, teletypewriter, communications and static reference file, the basic consoles are readily interchangeable in functional assignment and can thus back up one another. The configuration of test equipment is the only deviation from true universality.

The CRT's, keyboards, teleprinters and high-speed printer interface with the data processor through a display controller.

1.8 Processing

The processing subsystem comprises a data processor with core memory, a mass storage file, magnetic tape and a processor input/output interface unit. The data processor, under stored program control, performs a variety of functions in controlling the operation of the ATEC facility. Many of these functions have been mentioned in preceding paragraphs. Briefly, it steps the several monitoring scanners through their successive positions, accepts inputs from the various sensors or analyzers (after A/D conversion, where needed), compares the new readings against alarm thresholds, initiates fault isolation procedures, generates alarm displays on the console CRT's, accepts inputs and queries from the console keyboards, provides displays of requested data, updates dynamic data files, issues instructions to switching matrices, verifies cord patches, prepares reports to DOCC and O&M agency for edit and review, and performs numerous other actions.

The entire operating program is stored in the mass storage file (disc or drum), along with an extensive data base containing both static and dynamic data. The dynamic data base is constantly being updated as a result of equipment, unit, circuit monitoring and fault isolation, and by actions of operating personnel.

The magnetic tape file is used for initial program load into the processor and into the mass storage file and, subsequently, for the maintenance of a journal into which all significant events are recorded. The contents of this journal can be used later for retrieval of past data and for off-line analysis of operations by Central Control/System Performance and by the O&M agency or DOCC element.

The input/output interface unit provides a means for interfacing the high-speed input/output (I/O) bus of the processor with the normally much slower devices which share access to the bus, and for controlling the orderly sharing of such access through processor control.

1.9 Control Communications

Internal communications are facilitated through intercom exchanges at the operating consoles and other operating positions throughout the facility, and an intercom exchange switch that establishes the desired interconnections.

External communications for coordination with other ATECF's, with TCF's, with remote sites and repeaters, and with users are provided through conventional voice and teletype orderwires (express and maintenance). Access to AUTOVON, either directly or through on-base switchboard, is indicated as a necessary feature for coordination needed beyond the capabilities of the orderwires.

Also required are processor-controlled communication channels for reporting to DOCC and O&M agency and for direct inter-ATEC data exchange.

1.10 HF Transmitter and Receiver Sites

Representative implementation of ATEC capabilities at HF transmitter and receiver sites is shown on Sheet 3 of Figure 2. Monitoring of key equipment and link parameters is to be provided for each HF transmitting and receiving link. Where the intersite link to the ATEC facility uses line-of-sight microwave or [illegible] scatter plus frequency division multiplex, monitoring of such an intersite link will also be included, as indicated.

1.11 Repeater Site

Sheet 3 of Figure 2 illustrates the manner in which link and equipment monitoring information will be gathered at radio repeater sites and sent to the ATEC facility for processing. The outputs of the sensors are successively sampled by a scanner, converted to digital codes, and transmitted, via the telemetry subsystem, over a speech-plus service channel, to the ATEC Facility.

2. FACILITY ORGANIZATION

The specific operator actions and responsibilities of the personnel required by the ATEC facility are described in detail in the following subparagraphs. The interface complement of each operator position is described in detail in paragraph 2.4 of this section.

2.1 Central Control Position

This position is the central point for command and control of all activities at the ATEC facility. It will also be responsible for technical analysis and evaluation of system performance and system optimization. The person manning this position exercises a supervisory role and is responsible for:

a. Assignment of work loads to other console positions. Issuance of orders and coordination will be accomplished via intercom circuitry.

b. Maintain cognizance of station and system status. The central control operator will interrogate the processor for a report on whatever facet of operation is required to be known to aid in overall evaluation of circuits, equipments, links, or for determination of actions requiring data. Requests for information will be made through use of the keyboard and the data will be displayed on the CRT or on a hard copy printout.

c. Compilation, generation, review and release of all reports to elements of DCA and DA K operations. The Central Control operator will be responsible for originating station reports, and for final approval, as required, of

other personnel. The processor will have programs for generating reports and inputs to the processor will be made via a tape reader or keyboard. The report output will be provided on the CRT and/or hard copy for editing and also to a tape perforator to obtain a tape copy for transmission via an AUTODIN terminal.

d. Resolution of unique network problems. The Central Control operator will be called upon to make decisions concerning unplanned or emergency rerouting for restoral of service based on knowledge of station and system capability data obtained from the processor.

e. Provide assistance in activation of additional traffic circuits upon request by the users. From time-to-time, certain authorized users of the DCS may require increased communication channel capability on a temporary basis and the Central Control position will assist in coordinating with another user or TCF to establish the necessary circuitry. This coordination will be done via the available orderwire or telephone circuits.

f. Maintain control over the updating of the computer data base. The Central Control operator has the responsibility to ensure that periodic program changes to the processor are properly accomplished and to verify proper operation upon completion of such a change. A tape or card reader will be used for entering large program changes to the computer data base and the keyboard will be used for minor or routine [illegible] data changes.

g. Request and receive information from the processor on status of network, frequency usage and changes, reroutes, and equipment substitution. As part of the responsibility of Central Control, the operator, for various reasons, may need to know information such as DCS [illegible] for outages on circuits, channels or links. For an ATEC with operational control of HF transmitter and receiver sites, data on HF's frequency changes, in conjunction with a priori information such as propagation charts on MUF (maximum usable frequency), FOT (frequency of optimum transmission) and LUF (lowest usable frequency), will be required for evaluation of HF systems operation. Data on reroutes and equipment substitution will be used for evaluation of possible communication system reconfiguration. The data information will be obtained from the processor via the CRT display and on a hard copy printout.

h. Technical coordination with the DCOC (DCA Operational Control Complex), with other ATEC's or TCF's, organizational maintenance elements and appropriate O&M Operational and Maintenance support elements. The Central Control operator will have access to voice and teletypewriter orderwires, telephones and teletypewriter message transmission facilities for operational and technical coordination.

i. Technical supervision over subordinate TCF's and PTF's. The Central Control operator will be required to issue directions or orders for permanent, restoral and temporary circuits which may affect operations at subordinate stations. These orders may be in the form of teletypewriter messages or verbal orders, or both, depending on the actions, procedures, and stations involved.

j. Direction of the activation or deactivation of circuits, channels and links in accordance with circuit engineering orders (CEO). Upon receipt of a CEO, from a DCA element, the Central Control operator will direct the necessary action to implement the changes to be made. This may involve the ATEC facility itself, other TCF's and/or PTF's, local organizational maintenance, O&M agency elements and command elements. The necessary action directions may take the form of verbal and/or message orders and the Central Control operator will have the responsibility to ensure that the orders are being carried out at all equal and subordinate levels.

k. Reporting to higher authorities on the status of all communication media as prescribed by directives. Local or higher command elements may require generation of status reports. The Central Control operator will obtain verbal and/or hard copy information from reported-on stations, and station status from the processor to be used in preparation of such reports.

l. Coordination of the resolution of problems that cannot be resolved by the other ATEC facility operators. The other operators at the Status Monitoring and Quality Control consoles may, from time-to-time, require assistance in coordination with other TCF's or PTF's. The Central Control operator will have more experience in such matters and will be responsible for taking such action as may be required for resolution of the problem, whether it be technical, operational or personnel.

m. Performance of required administrative functions. Although the Central Control position is of an operational nature, there will be certain responsibilities concerning administrative matters that, nonetheless, must be performed. These matters may range from personnel reports and evaluation to analysis of other support activities.

n. Preparation of logs. The information necessary for preparation of the station logs, particularly the Master Station Log, will be obtained in hard copy from the processor. The Central Control operator will generate and review the daily station log and make entries as necessary.

2.2 Status Monitoring Positions

At each ATEC there will be one or more status monitoring consoles. The quantity of consoles will depend on the number and types of circuits, equipments, and links at a particular ATEC station and also upon the operational requirements. The status monitoring position will be used to perform normal Tech Control functions associated with providing telecommunications service to users of the DCS. To these positions, will be provided the initial indication of impending faults, degraded performance (Amber condition) and failure occurrence (Red condition) of circuits, equipment and links. The following is a listing of operator actions and responsibilities that will be required of, or delegated to, the status monitoring positions.

a. Coordination with other ATEC facilities and TCF's in matters pertaining to changes or restoral's of links, channels and circuits for which they share responsibility. The status monitoring operator will be responsible for maintaining cognizance over such changes as may be necessary to preserve or restore telecommunications service. The operator will use voice or teletypewriter orderwires, mainly, in coordinating with status monitor positions at other ATEC facilities and with Tech Control personnel at the manual TCF's.

b. Technical direction of subordinate TCF's and PTF's on all matters pertaining to links, channels and circuits for which the ATEC has responsibility. The status monitoring operator will handle all incoming requests for checking circuits, via voice or teletypewriter orderwires, and by telephone if no orderwire exists to a particular PTF or user. The operator will be able to access the particular circuit in question, via a test bus, after calling up the circuit with a keyboard generated instruction to the processor. The operator will then use test equipment to monitor, analyze or insert a test signal to check performance, and will initiate any changes that may be necessary to restore service.

c. Coordination with local users on matters pertaining to communications and service. The status monitoring operator will coordinate with such users, usually by telephone, and provide assistance, as required.

d. Restoration of service to users, utilizing predetermined alternate means, in accordance with established NCS restoration priorities. Upon loss of service or knowledge of impending outage, the status monitoring operator will be responsible to take necessary action to effect restoral or continuation of service. The operator will have

access to stored data files containing information on priority, profile and reroutes. Normal restoral action will usually involve channel substitution with a spare channel; however, in cases of link failure, group restoral methods will be implemented. Switching of channels or groups will be effected through keyboard generated instructions to the processor which, in turn, will cause the required switch matrix connections to be made. These actions will require coordination with other ATEC's, TCF's, PTF's and users, and, in addition, follow-up action to effect normalization of circuitry and systems by coordination with maintenance, remote sites providing telecommunications channels, or commercial common carriers. At certain times, reroute action may require preemption of channels assigned to users with lower priority circuits. The lower priority users must be notified of the preemption action and the operator will be responsible for coordinating the outages with directly connected users or with subordinate TCF's and PTF's at which the preempted circuits terminate.

e. Activation, deactivation and rearrangement of circuits, links, and equipment, as directed by local SOP's (standard operating procedures) or as directed by the Central Control console operator. The status monitoring operator will have responsibilities of testing, monitoring and verifying performance upon activation, and also of coordinating the deactivation or rearrangement actions required, according to procedures or direction received from Central Control. The coordination will be done using the intercom, voice or teletypewriter orderwires, and telephones as necessary. The operator will access the circuits or channels of interest for monitor and test purposes by keyboard generated instruction to the processor, which will bring up the circuit or channels on test buses which appear at the consoles. The operator will then be able to monitor activation, deactivation or rearrangement, as required, and verify that what was to take place, has taken place.

f. Preparation and entry, for report purposes, of narrative information on unusual occurrences such as unplanned station outage, or interference on assigned radio frequencies. Following determination of such an RFO, the status monitoring operator will convey the information to the Central Control operator and also make the required entry, via a keyboard, of the necessary elements of the report into the processor.

g. Coordination with remote HF transmitter and receiver sites on frequency changes and channel usage. The status monitoring operator will have the responsibility of effecting frequency changes, as required,

on HF ISB links when the ATEC facility is the control station for the remote HF sites. The operator will be automatically notified, through sensor action and telemetry, when the receive link of a HF ISB link requires frequency change; i.e., it goes into Amber condition because of reduced or fading receive signal strength. The operator, through means of a stored data file, can ascertain which frequency of the ones assigned for use on the particular link should be used and can request a check, via the orderwire, on the frequency by the remote receiver site. This is done to determine that the frequency selected is clear or usable. The operator will then contact the ATEC facility or TCF at the distant end of the HF link, by means of orderwire, and direct the QSY (frequency change) to be made. The HF receiver site, already notified of the QSY, will report back when the action has been completed. In cases where there is only a single transmitter for the particular link at the distant end, there will be an interruption of service and the status monitoring operator will use orderwires to notify the local users or other TCF's, at which the circuits on the HF ISB link terminate, of the outage and of restoral upon completion of the QSY. The operator will also perform complementary actions, when a frequency change is requested by the distant end TCF, in directing a QSY to the HF transmitter site and notifying the users and TCF's, again, of the outage via orderwires. In cases where spare or simultaneous HF transmitters and receivers are available, the outage can be eliminated, although there will be a slight disruption when switching from one to the other diversity receiver set, at the audio outputs.

h. The status monitoring console positions will be the point at which the Tech Controllers will be notified of troubles that may have occurred. Sensor and monitoring information, via telemetry or in-station communication media, will be displayed at the console when an Amber or Red condition is detected on either circuits, equipments, or links. The operator will be able to interrogate the processor, through the keyboard, for additional information from the stored data base, as required, to determine the next course of action to be made to correct the condition. The requested information will also be displayed at the console position. The sensor and monitoring information will, in addition to fault detection, be used for fault isolation; to identify and localize the trouble.

i. The status monitor operator will be responsible for making entries into a stored data file via keyboard, thus recording Tech Control activities. The stored data file will actually be a tape transport providing recording capability on magnetic tape. The information will be

used to compose the daily station log. The recorded information will consist of outage reports, action reports, service reports and maintenance requests on circuits, channels, equipment and links. Automatic time insertion will be provided for each log entry.

3. Operational direction, coordination and supervision over transmission links, channels, circuits and equipment operating in the ATEC facility. The status monitoring operator will also be similarly responsible for remote HF transmitter and receiver sites, LOS and tropo radio relay sites, and automatic switching sites when they are under direct operational control of the ATEC facility. The operator will have access to voice and teletype orderwires which terminate at these sites and also to interconnecting circuitry for inter-ATEC coordination purposes. Profiles on links, channels, circuits and equipment will be available for display at the console. The operator will also have access to stored data on ATEC facility operation and other information stored in the computer data base. The status monitoring operator will be capable of entering instructions, via keyboard, to group, circuit and digital switching matrices for rearrangement of circuits and channels which have been provided with access to these switching matrices. Status information will be provided from sensor and monitoring devices for fault prediction, detection and isolation.

1.3 Quality Control Position

As presently constituted, the Tech Controllers have the responsibility of maintaining quality monitoring over circuits, channels, links and equipment, both operational and spare, under control of the TCF. In the ATEC facility much of the quality monitoring will be performed through the use of sensors and monitoring equipment. However, there will still be a need for a quality control console position to provide more detailed testing and monitoring of selected circuits, channels, links and equipment. The quality control position will be provided with testing devices such as the multiparameter VF channel test sets which will permit detailed tests to be performed in much less time than is now possible in a TCF. This position will be used for monitoring on selected circuits or channels which, because of priority or instability, require closer attention than other circuits or channels. By being selective in function, the quality control position will also be able to handle assignments from the Central Control and status monitoring positions, for more extensive testing than is possible at either of these two types of consoles. The quality control position will therefore be taking some of the load off the status monitoring operators and allow them to not get tied up on a particular problem which may require extended or extensive testing. The following paragraphs detail the actions and responsibilities of the quality control console position and operator.

a. Performance of quality monitoring and testing, on a predetermined basis, of spare lines, channels, links and equipment to ascertain their availability. The quality control operator will have the responsibility to ascertain, verify and record that certain spare items and services are capable of use when needed for either reroute or restoral action. Schedules will be used to determine which spares are to be checked within a certain time period. The operator will have the capability of accessing the spare items and services, through use of a keyboard generated instruction and a flexible pick-up of monitor and test boxes, to perform the necessary tests and verify availability. CRT display and hard copy printouts will be provided for stored data and test data, respectively. Intercom circuitry and voice and teletypewriter orderwires will be used for coordination with Central Control, status monitoring and other ATSC facilities, TCF's and PTF's, as required.

b. Performance of quality control testing, on a predetermined basis, of circuits or channels normally used for operational traffic in conjunction with scheduled maintenance or out-of-service periods. The quality control operator will be required to coordinate with Tech Control personnel at other ATSC facility, TCF's and PTF's in order to accomplish testing of operational circuits during the aforementioned idle periods. The operator will use the features provided for circuit and channel testing to determine that these Communication media are acceptable for resumption of service.

c. Provision of assistance to the status monitoring console positions on circuits, channels, links or equipment requiring extensive and prolonged testing to determine and correct deficiencies. The quality control position will have test features with capability above that provided to the status monitoring positions. Coordination of assistance will be accomplished via intercom. The quality control operator will be called upon at times to assume responsibility over problems hampering the status monitoring operators and thus allow the status monitoring positions to concentrate on detection, restoral, reroute and coordination functions.

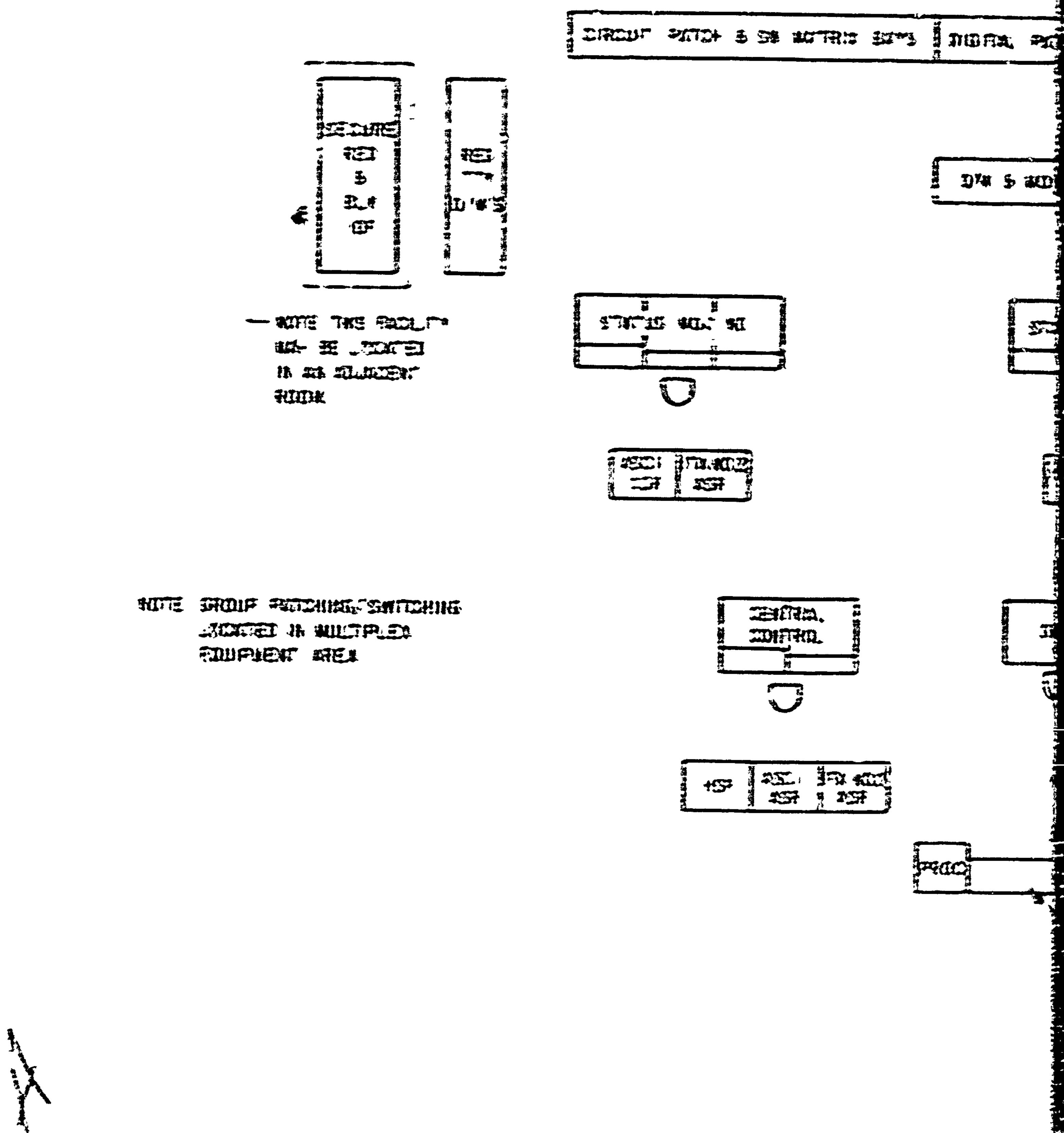
d. Coordination of quality control activities with TCF's, PTF's and users. The quality control operator will be able to selectively access voice and teletypewriter orderwires and telephones, as necessary, to carry on the required quality control and monitoring functions. Coordination of user-to-user testing will be a responsibility of the quality control operator to verify the need for such tests and to assist in restoring normal operation as soon as possible.

e. Implementation of directions received from the Central Control position. The quality control operator will be given tasks, by the Central Control operator, for assessment of circuits, channels, links and equipment, prior to rearrangement or reconfiguration, whether for engineering or operational purposes. The Central Control operator may send him, for example, on a particular digital circuit that has been brought to the attention of DCA or the O&M agency by the user's headquarters. The circuit may only pass through the ATEC facility, but because it is so essentially for mitigation, consideration may be given to placing a representative operator at the send and receive channels to improve service. The quality control operator will perform an analysis, over a period of time, and provide data and recommendations to the Central Control operator for correction of deficiencies in the circuit.

f. Preparation of entries into the station log. The quality control position will be responsible for generating records of activities that are required to be recorded. The operator will note completion of scheduled routine quality monitoring and any deviations that should be brought to the attention of maintenance. Unusual or unscheduled quality control and monitoring activities will likewise be recorded. The quality control operator will generate the entries by means of a keyboard and will use the display for editing prior to insertion into the disk storage used for logging purposes.

[illegible] Other ATEC Operations

In addition to the operator positions already defined and analyzed, certain additional operational personnel will be required to permit accomplishment of the remaining tasks within the ATEC facility. The most significant of these are the operators who will be required to accomplish manual patching. As indicated earlier, switching may be accomplished to some degree, but manual patching is still expected to be of major importance, at least in the first generation of ATEC. It is estimated that, with switching patching provided in the manner and to the degree described in paragraph [illegible] of this section, for a major station three operators will be required to handle the manual patching requirements and associated restoration and monitoring functions (Reference Figure [illegible]). These operators will respond to the requests of the operators at the console positions with respect to establishing circuit patches and equipment patches for both restoral and testing purposes, e.g., loop-backs. This activity will be accomplished primarily via the test board described in paragraph [illegible]. Requests from other TCF's or ATEC facilities regarding patching or monitoring will normally be received by one of the console positions and will be accomplished either by the operator at that position or by the manual patch bay operators under direction of the



CIRCUIT PATCH & SW MATRIX EQPT
NOTE THIS FACILITY MAY BE LOCATED IN AN ADJACENT ROOM
CENTRAL CONTROL
NOTE GROUP PATCHING/SWITCHING LOCATED IN MULTIPLEX EQUIPMENT AREA
PROC

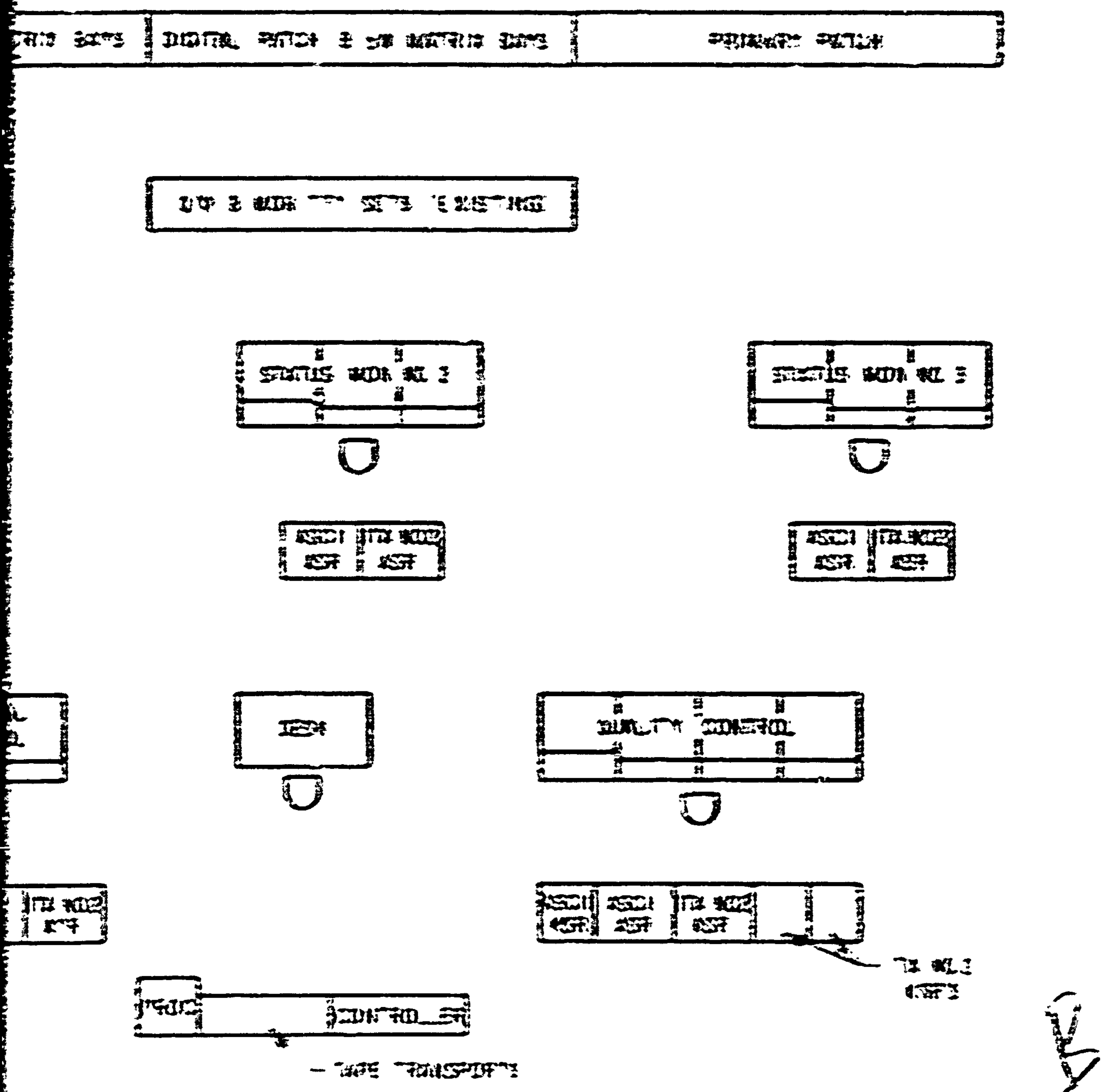


FIGURE 7
OPERATIONAL AREA
CONFIGURATION

console operator. All patching must be coordinated by the console operators to ensure current status of the data base available to the operators.

7.5 Interrelationship with Maintenance

Tech Control is responsible for operational direction to maintenance. The Central Controller, or his designated representative, is responsible for all coordination with maintenance, for the development of maintenance schedules in cooperation with maintenance, for the establishment of maintenance priorities, for the coordination of maintenance requiring service interruptions, for the coordination of acceptance testing of repaired or realigned equipments and channels, and for final acceptance of such equipments and channels.

The status monitoring operators and the quality control operator are responsible for supporting maintenance to the greatest extent possible. They must isolate the fault as accurately as possible, obtain the latest in-service performance data at the time of failure, provide accurate details of the symptoms and circumstances at time of failure, and provide proper identification of the failed element to be turned over to maintenance. This information as well as all other information required by the maintenance work order described in paragraph 2.4._ of Section II must be provided for each item turned over to maintenance. This information should be displayed in its complete form at the status monitoring operator, should be relayed via the processor to the Central Control position for the supervisor's verification and approval, and should finally be printed out as a hard copy of the maintenance work order on a KSR. KSR set at the maintenance supervisor's position. The maintenance supervisor should insert in the processor via the KSR keyboard the information to be supplied by maintenance, such as estimated time of completion. The supervisor will also be able to query the processor regarding additional specific information, e.g., performance characteristics, data concerning test conditions as performed, or past performance record of item presently being maintained. Coordination via intercom or interphone between maintenance and the quality control position or the status monitoring positions is required to permit maintenance personnel to obtain the assistance of the operators in accomplishing and verifying repair and alignment.

3. TECH FACILITY DETAILED DESCRIPTION

1. Sensing, Scanning and Testing Facilities

The purpose of this subparagraph is to define the equipment hardware requirements to meet the concept of sensing, scanning and testing developed in Section II, paragraph 3._ and in the simulation study that appears in Sections VI, VII, IX, and XI of Volume I.

7.1.1 Equipment Unit Sensing

Analysis of the link status and monitoring and the equipment status and monitoring study tasks (Sections VI and VII, respectively) reveals the need for four types of sensors to accomplish equipment and link monitoring. These four types include DC, AF, RF and MW sensors to cover the frequency ranges of interest. In the interest of standardization, these sensors are to conform to the facility requirements outlined herein. Input characteristics of the sensors must be compatible with the signal type (point) being sensed, including frequency, level, and impedance. Input isolation is required such that no appreciable degradation occurs to the signal being sensed. Failure of the sensor input circuitry will have no adverse effects on the signal being sensed. Some signals being monitored undergo normal, rapid level changes. Provisions are to be included such that these rapid level changes are not reflected in the sensor's output, thereby avoiding the possibility of a "false alarm." The sensors are to be capable of providing the full range of output for a specified range of input levels. The output characteristics of all sensor types are to be standardized as to level and impedance. All sensor outputs must be of a single polarity to eliminate the need of sign identification in any subsequent level conversion. In order to minimize the possibility of noise "pick-up", the sensors are to have a low output impedance characteristic.

It is not likely that any two sites in the DCS will require the same quantity of sensors or sensor types. Further, future changes to the DCS (such as digital links) may well require an increase or decrease of the quantity of some sensors and sensor types required. Therefore, modularity in the sensor design is highly desirable. Preferably, each sensor type should be a single entity, capable of being added to or removed from a common sensor mounting chassis.

7.1.2 Equipment Unit Scanning

The requirements of scanning and sensor level conversion, by means of an analog to digital converter, were analyzed and developed in the Transmission Analysis Study Task, Section XI. The requirements outlined herein are a combination of the study task recommendations and the overall system considerations; the prime system consideration being the need to scan all sensors in a period of one minute to two minutes as developed in paragraph 3. . 4 of Section II. The function of the scanner converter is to transform the sensor outputs into a form suitable for transmission and eventual inputting to a remote processor, or for direct input to a local digital processor. The scanner converter input must be compatible with the sensor outputs. The scanner's capacity (number of inputs) is dependent upon the following:

a. Number of sensors to be scanned in one minute is [illegible] hundred.

b. The sensors are performing an integration (sample and hold) function, thereby permitting a short dwell time (less than one second) which allows rapid scanning.

c. Cost-effective employment of a scanner requires that the capacity of the scanner be maximized.

Typically, scanners operate at 50 inputs/second. This allows up to 3000 points scanned in one minute, which should be more than sufficient for any one DCS location. Expansion capability is needed in the scanner's capacity to adjust to future site expansions. Since the processor of the controlling element is ATEC, the scanner must be capable of being externally controlled. Maintenance and correction of the scanner (unlike sensors, control and readout at the scanner location) is highly desirable. Detection of the readout to the processor is also desirable to maintain synchronization. The quality of the readout point must be such that no appreciable change occurs in the sensor level, thereby resulting in a "true" sensor level after conversion.

3.2.3 Equipment Unit Testing

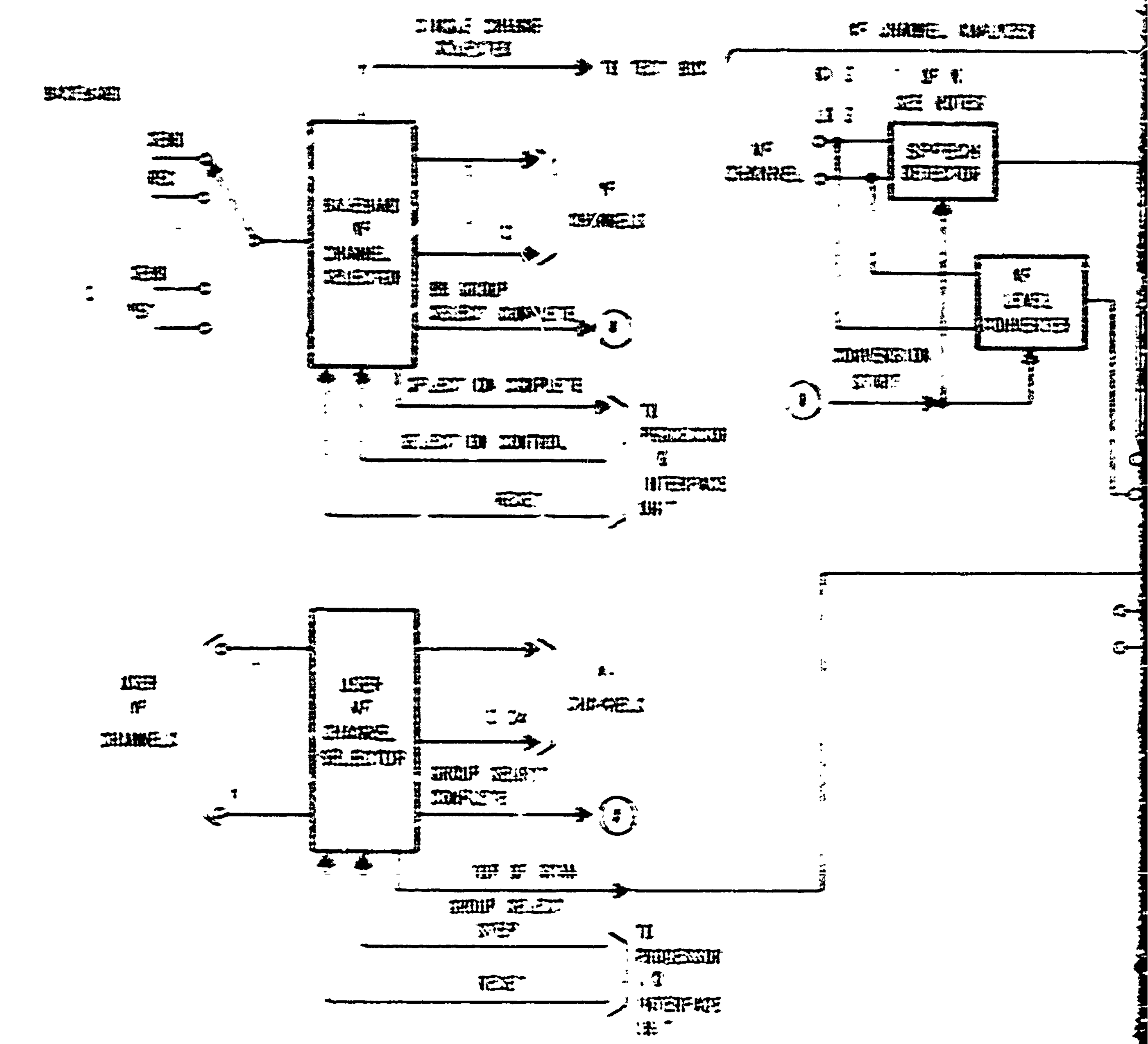
The testing requirements as determined in the Equipment Status and Monitoring Study Task (Section VIII) were to provide full performance analysis of HF transmitters and receivers on an off-line basis, e.g., during down-time or frequency change periods. However, due to the cost-effectiveness study, it was determined that routine maintenance checks would suffice for these equipments and therefore the performance analyzers are not required.

3.2.4 Circuit Sensing and Scanning

The Circuit Status Monitoring Study task (Section IX) developed the basic requirement for sensing, scanning and testing of analog and digital circuits. Tradeoffs and integration into the overall system concept resulted in some modifications to the recommendations made in that study task. The requirements contained herein reflect the final requirements.

3.2.4.1 Analog Circuits

The functional interconnection of the devices required for scanning and sensing analog circuits is depicted in Figure 4. These equipments provide the capability of analyzing all analog circuits appearing at a site. Both drop circuits and through circuits are accommodated. The user VF channel selector is associated with the receive drop circuits, while the transmit VF channel selector


SELECTION CONTROL
RESET

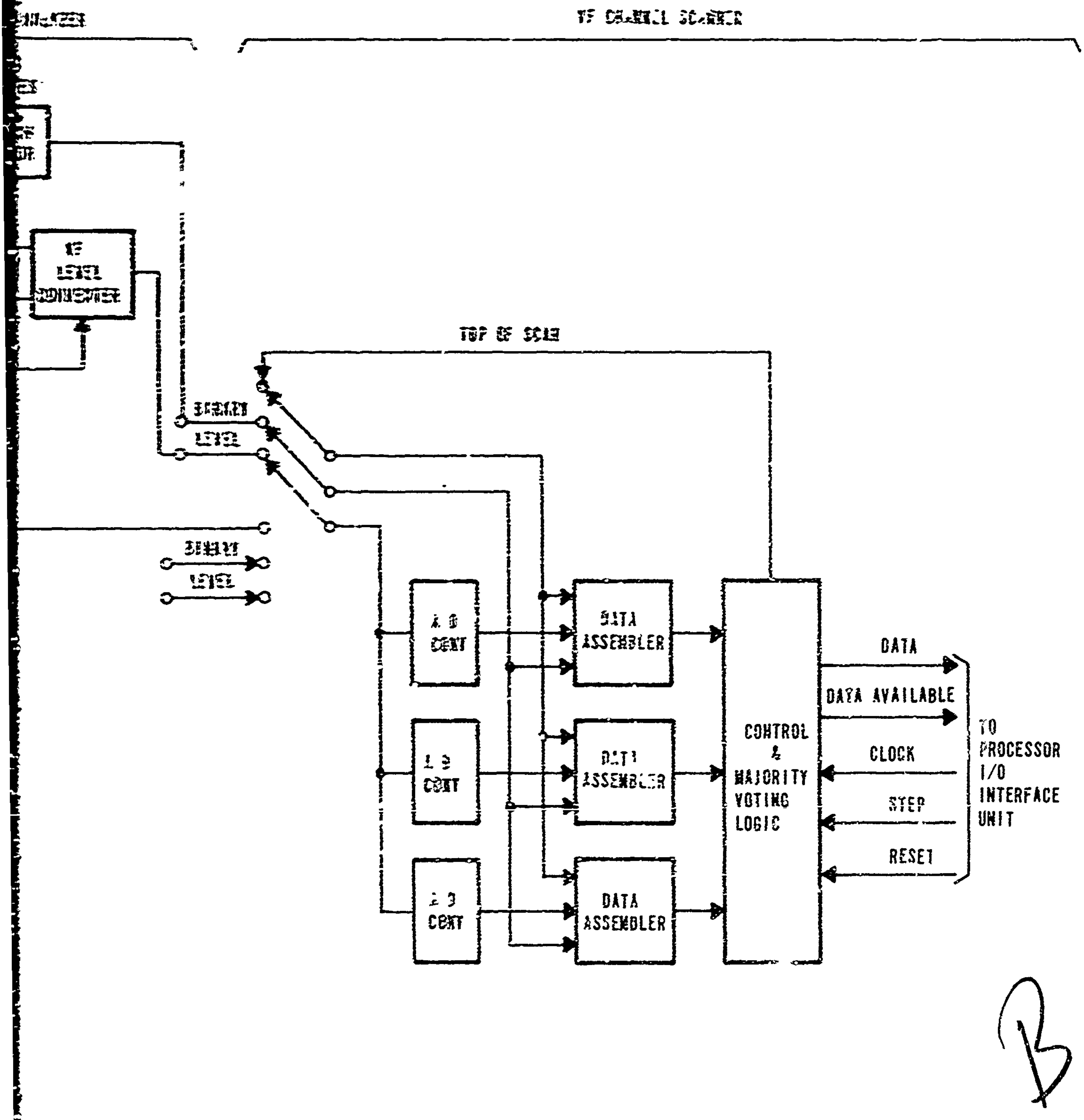


FIGURE 4 ANALOG CIRCUIT SCANNING AND SENSING FUNCTIONAL DIAGRAM

demodulates the baseband signals to the VF channel level. At this point all VF channels (from both the user VF channel selector and the baseband VF channel selector) are analyzed to determine what level is present and whether or not the channel is carrying speech traffic. Speech identification is essentially required on alternate voice data circuits where the voice levels encountered may be the same as the supervisory tone level. On other circuits (voice with no supervisory, continuous VFCT or data traffic) the processor "knows" what is present and can more readily perform a signal to noise measurement; due to the normal existent wide range of level differences between the traffic and noise levels. The VF channel scanner converts the level from the analyzer and assembles the information, for input to the processor.

All devices shown, with the exception of the analyzer, are under control of the processor, via the processor I/O (input-output) Interface Unit. Synchronization between the processor and the user VF channel selector as well as the VF channel scanner is maintained by the top-of-scan identifying code in the data. The baseband VF channel selector, which has the capability of random access, maintains synchronization with the processor by sending the selection control instruction to the processor after completing the selection. The random access feature is required to permit rapid access and analysis of any receive channel. at the baseband level, when an abnormality is uncovered at the receive side drop point. This feature is the first step in fault isolation.

To achieve standardization, all digital interfaces between the devices shown on Figure 4 are to conform to MIL-STD-188B, standard interface, low level.

a. Baseband Voice Frequency Channel Selector

This device is required to demodulate baseband signals to the VF channel level such that both one group of VF channels (12) or any one VF channel of the group is available for subsequent analysis. Selection capability of up to five transmit and receive baseband signals is required. Two baseband modulation plans are to be accommodated, one for twin sideband and one for lower sideband in accordance with CCITT recommendations. Manual and external control, of random access of the group and channel selected, with appropriate readout is required. A maximum demodulation rate of one group per 180 milliseconds is required per system requirements developed in paragraph 2.1, Section III. The demodulation performance characteristics are to be as good as or better than that of the receive terminal of the multiplex equipment normally receiving the baseband signal. Input isolation from the baseband

signal is to be included such that during normal operation, or in the event of failure of the device's input circuitry, no appreciable degradation is experienced by the baseband signals. Self-testing features are required to permit independent check-out of the device.

b. User Voice Frequency Channel Selector

This device is to be capable of sequentially scanning VF channels such that groups of 12 or 24 channels are made available for subsequent analysis. Input channel capacity is to be from 12, minimum, expandable in increments of 12, up to a maximum of 720. Manual and external control of the scan rate, including readout of the scanner's location, is required. Maximum scan rate will be one group per 180 milliseconds as in a. above. No appreciable degradation is to occur to the VF signals in passing through the scanner. Self-testing features are to be provided to permit independent check-out of the device.

c. Voice Frequency Channel Analyzer

This device is to convert a VF signal to a DC voltage and identify the signal level converted as speech or not speech. The signals presented to the device may be VFCT, data modem, signaling, noise or speech traffic. The device is to be capable of bridging or terminating 600 ohm, balanced, VF channels with no appreciable degradation to the input signal when in the bridging mode. The conversion and identification time is not to exceed 500 milliseconds per requirements in paragraph 2.1. Section III. The level sensor is to exhibit characteristics similar to the AF sensors described in paragraph 3.1.1 of this section.

d. Voice Frequency Channel Scanner

This device is to be capable of sequentially scanning the VF channel analyzer's outputs and converting the DC level signals present to a digital serial stream of data for inputting to the digital processor. Minimum input capacity is to be 14 (two for use on test buses), expandable in increments of 12, up to a maximum of 74 inputs. A six-bit level conversion is required, nominally, for incremental quantization of the input signals. Two sequential inputs are to be assembled into one 16 bit output. For increased reliability, triple redundancy and majority voting logic is required. Manual and external control of the scanning, with scanner location readout,

is to be provided. Maximum scan rate will be 65 inputs per second. Self-testing features are to be provided to permit independent check-out of the device.

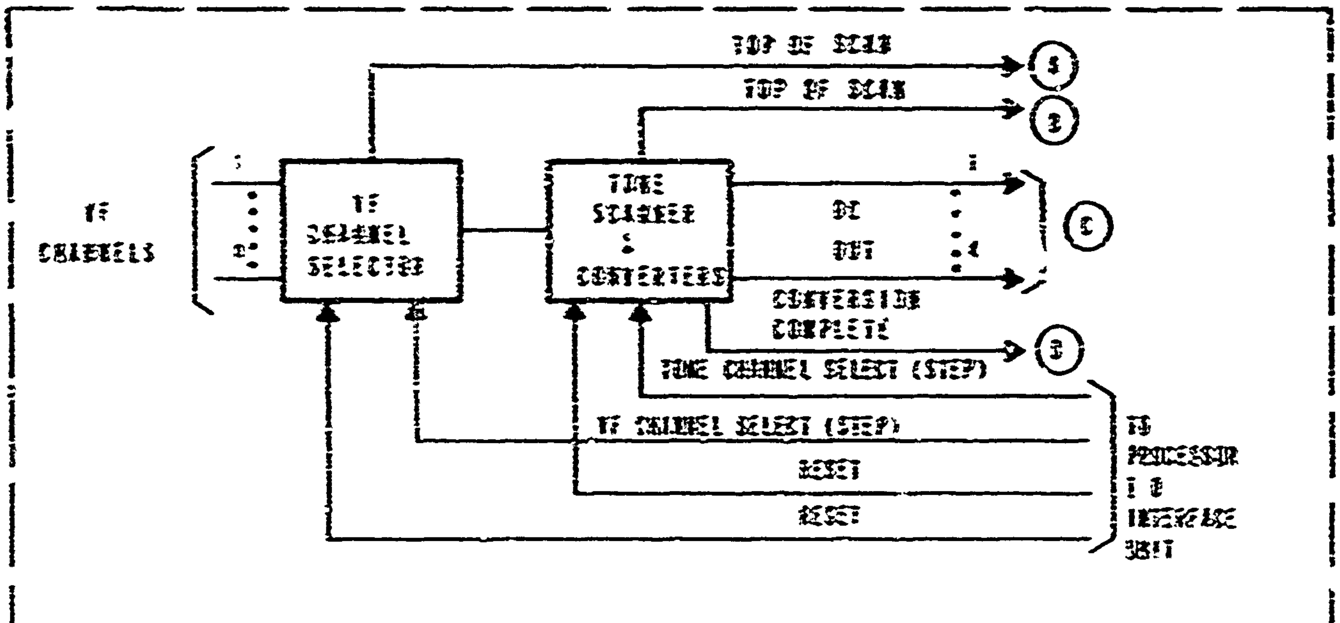
3.1.4.2 Digital Circuits

Monitoring of digital circuits is to be performed at two points; at the DC drop point and at the VF channel level. Figure 5 depicts the functional interconnection of the devices required for monitoring at the VF channel level. Figure 6 depicts the DC drop monitoring device.

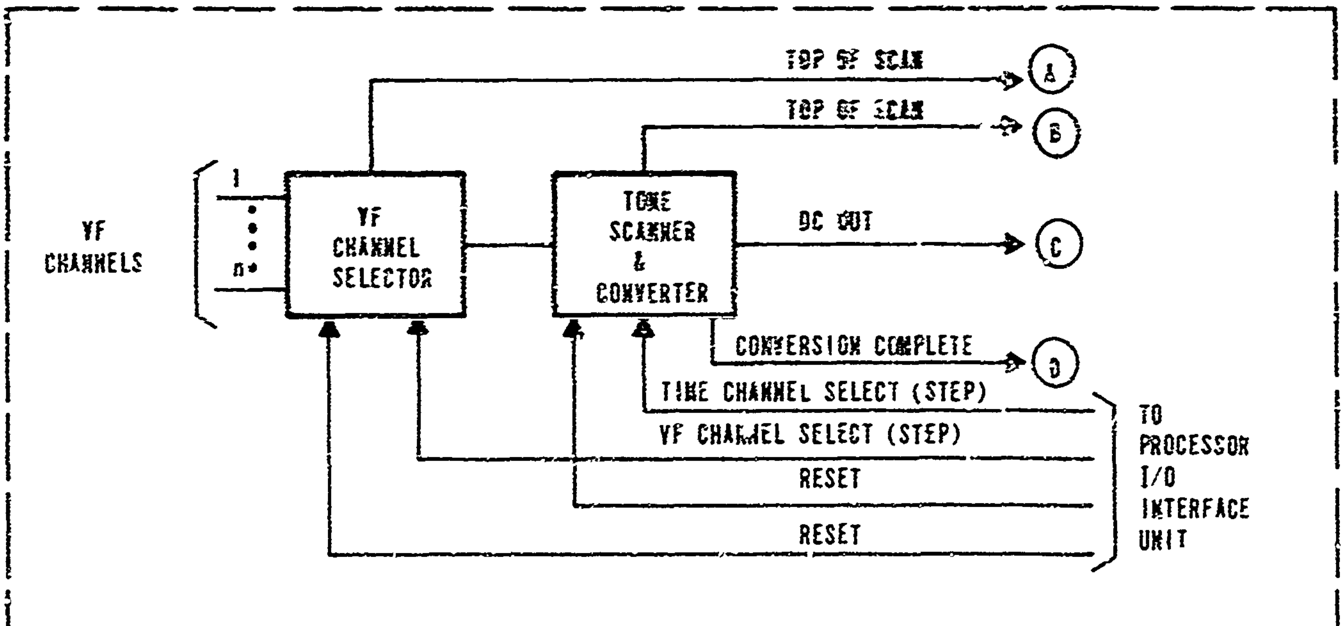
These equipments provide monitoring of all DC circuits appearing at a site. The VFCT tone scanners (FSK and PSK types) provide access to through circuits by "breaking-out" the tone channels from the VF channels passing through the circuit patch and converting the tones to DC signals. At this point the remote controlled distortion analyzer determines the total (peak) distortion and peak count of the DC signal. The results of the measurements are assembled for inputting to the processor. The automatic digital circuit analyzer performs similar measurements, at the DC drop point, for inputting to the processor. All devices shown on Figure 5 are under control of the processor. Both scanners provide top of scan identification bits, for the VF channel selection and the tone channel selection, to maintain synchronization with the processor. Speed selection and unit interval code (including synchronous data selection) selection, in the remote controlled distortion analyzer, is under control of the processor; the processor being the device which "knows" the nature of the signal being analyzed. To achieve standardization, all interfaces between the associated digital circuit monitoring devices are to conform to MIL-STD-188B, standard interface, low level.

a. VFCT Tone Scanner (FSK)

This device is required to "break-out" FSK tone channel from VF channels and convert the tones to DC signals for subsequent analysis. The minimum VF channel input is to be six, expandable in increments of two, up to a maximum of 50 channels. Due to the high quantity of FSK tone channels normally in use, four tone channels are to be converted to DC signals, simultaneously. The device must be capable of converting 16 FSK tone channels with 170 Hz spacing of center frequencies from 425 Hz to 2975 Hz with a frequency shift of $\pm$ 42.5 Hz. The keying rate of any one tone channel will not exceed 90 baud. The device is not to add more than a minimum amount of distortion (less than 1 percent) to the signal during the selection and conversion process. Manual and

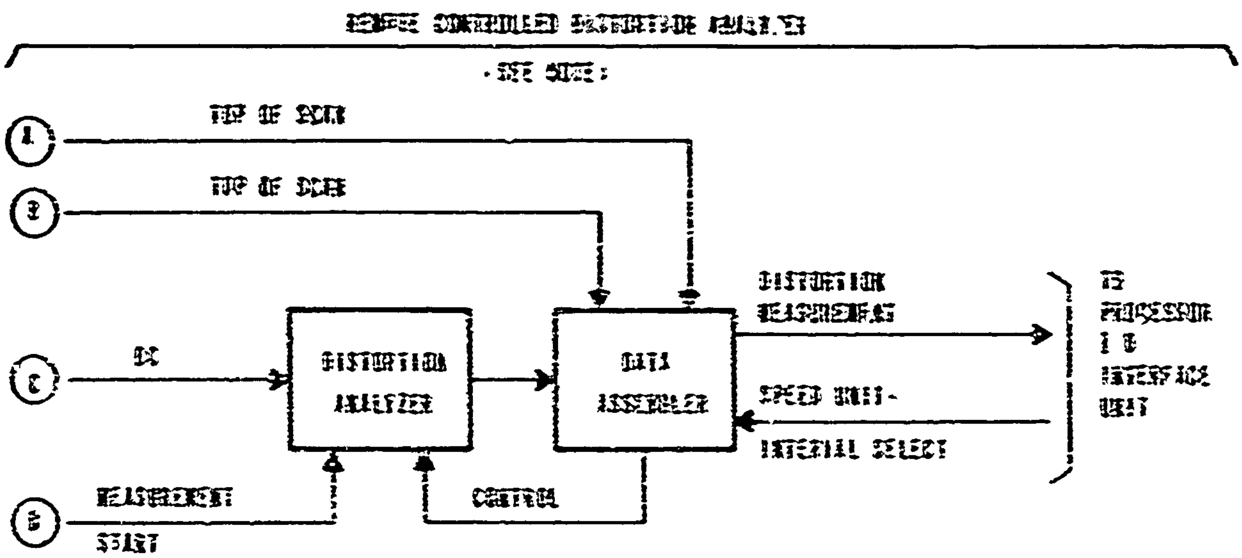


VFCT TONE SCANNER (FSK)



VFCT TONE SCANNER (PSK)

A



NOTE FOUR (4) REMOTE CONTROLLED DISTORTION ANALYZERS FOR EACH VFCT TONE SCANNER (FSX). ONE REMOTE CONTROLLED DISTORTION ANALYZER FOR EACH VFCT TONE SCANNER (FSX)

FIGURE 5 DIGITAL CIRCUIT MONITORING AT THE VF CHANNEL LEVEL

B

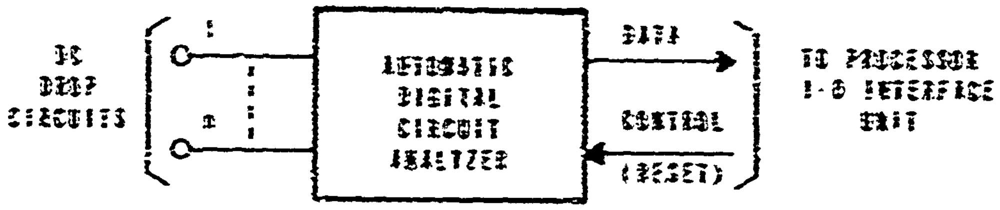


FIGURE 6
DIGITAL CIRCUIT MONITORING
AT DC USER DROP

external control with appropriate readout of the tone channels being converted is required. A minimum conversion rate of four tone channels per second is required. Self-testing features are required to permit independent check-out of the device. Input isolation from the VF channels is to be included such that during normal operation, or in the event of failure of input circuitry, no appreciable degradation is experienced by the VF channel signals.

b. VFCT Tone Scanner (FSK)

This device is required to "break-out" FSK tone channels from VF channels and convert the tones to DC signals for subsequent analysis. The minimum VF channel input is to be four, expandable in increments of two, up to a maximum of 12 channels. One tone channel is to be converted at a time. The device must be capable of converting 12 FSK tone channels with 100 Hz spacing at center frequencies from 350 Hz to 3450 Hz with a phase shift of $\pm 340^{\circ}$. The keying rate of any one channel will not exceed 50 baud. The device is not to add more than a minimum amount of distortion (less than 1 percent) to the signal during the selection and conversion process. Manual and external control with appropriate readout of the tone channel being converted is required. A minimum conversion rate of one tone channel per second is required. Self-testing features are required to permit independent check-out of the device. Input isolation from the VF channels is to be provided such that during normal operation, or in the event of failure of input circuitry, no appreciable degradation is experienced by the VF channel signals.

c. Remote Controlled Distortion Analyzer

This device is to analyze DC signals of various speeds for total (peak) distortion and peak count, and assemble the results into ASCII format for inputting to a processor. Start/stop or synchronous DC signals operating at speeds of 37.5, 45.5, 50.0, 56.8, 61.1, 74.2 and 75 baud with up to 45 percent distortion are to be accommodated. The measuring accuracy is to be $\pm$ 2 percent for distortion and $\pm$ 1 count for peak count. Self-testing features are required to permit independent check-out of the device.

d. Automatic Digital Circuit Analyzer

This device is to be capable of scanning DC circuits and measuring the total (peak) distortion, peak count and average distortion of the

signals present. The minimum capacity is to be 50 DC circuits, expandable in increments of 50, up to a maximum of 250 circuits. Measurement capability of start-stop or synchronous digital circuits operating at speeds of [illegible], 45.5, 50.0, 56.9, [illegible], 74.2 and 75 baud with up to 45 percent distortion is required. Two circuits are to be analyzed simultaneously. The results of the measurements are to be assembled into ASCII format including the circuit identification for inputting to a processor. Two modes of operation are required: output the results of all circuits analyzed, and output the results only on those circuits which have exceeded a selected threshold. Separate threshold selection on each input is required. Measurement accuracy is to be ± 1 percent on total (peak) distortion, ± 2 percent on average distortion and ± 1 count on peak count. Input isolation from the DC circuits is to be provided such that during normal operation, or in the event of failure of the input circuitry, no appreciable degradation is experienced by the DC signals.

3.1.5 Testing

The testing requirements, as determined in the Circuit Status Monitoring Study task, Section IX, include a multi-parameter test analyzer and impulse noise counter. Both devices are to be used on an off-line basis. The multi-parameter test analyzer, with its inherent capability to perform analysis in a relatively short time period, may possibly be employed randomly on idle circuits. Its primary use, however, should be to perform the normal periodic routine circuit maintenance checks. Its rapid operation and printout of results feature (no need for an operator to read meters and interpret results) should prove a valuable tool in circuit testing. The system design effort also revealed the need for other testing devices, which may be considered standard off-the-shelf equipments.

3.1.5.1 Voice Frequency Channel Multi-Parameter Test Analyzer

This device is to consist of a test-transmitter and analyzer for performing multi-parameter tests of VF circuits. Provisions are required to permit collocating or separately locating the transmitter and analyzer. Loop-back testing capability is required (testing incoming and outgoing circuits) as well as single direction testing. Parameters to be measured include line loss, frequency response, envelope delay, signal-to-noise ratio, non-linear amplifier distortion, frequency offset (translation) and short term frequency stability (phase jitter); manual (via associated teletypewriter) or automatic (via an external processor) operating capability is required. All input control data and output test results are to be in serial form. Circuit measurement time is not to exceed one second and capability for manual (patching) or automatic (external switching device)

connection to the circuit(s) to be tested as required. Self-testing features to permit independent checkout of the device are to be provided.

3.1.5.2 Standard Off-the-Shelf Analog Test Equipment

An impulse noise counter and other devices such as a noise meter, VTVM, VU meter, AF signal generator, monitor speaker panel, frequency selective voltmeter, envelope delay measuring set and a spectrum analyzer are required for off-line and on-line testing and analysis. Listed below are various manufacturers' model numbers (or equivalent) which can meet the functional requirements of these equipments.

Standard Off-The-Shelf
Analog Circuit Test
Equipments

Nomenclature	Model Number
Impulse noise counter	Northeast Electronics TTS-58A, or equivalent
VTVM and noise meter	HP 3556B, or equivalent
VU meter and monitor line amplifier	TeleSignal 420B, or equivalent
AF signal generator	HP 205AG, or equi alent
Envelope delay measuring set	Sierra 340B, or equivalent
Spectrum analyzer	Sierra 360A, or equivalent (used with 128A, below)
Frequency selective voltmeter	Sierra 128A, or equivalent

3.1.5.3 Standard Off-the-Shelf Digital Test Equipment

The testing requirements as determined in the Circuit Status Monitoring Study task, Section IX, include a manually operated distortion analyzer test set and a bit error rate tester (Data Transmission Test Set). Both these items are readily available as off-the-shelf items. Listed below are manufacturers' model numbers (or equivalent) which can meet the functional requirements of these equipments.

Standard Off-The-Shelf
Digital Circuit Test
Equipments

Nomenclature	Model Number
Distortion Analyzer Test Set	Digitech [illegible], or equivalent
Data Transmission Test Set	Fredericks [illegible], or equivalent

3.2 Switching and Patching

3.2.1 Background

The purpose of the ATEC patching facilities is to provide automated and manual patching, monitoring, and testing for the group, voice channel, and DC circuits serviced by an ATEC center. These facilities have been conceived to fully complement and support the ATEC switching and patching operational concepts developed in preceding sections of this report. The purpose of this paragraph is to describe the recommended facility configurations and the methods of hardware implementation selected as being the most cost-effective.

The patching/switching problem is investigated in detail and is discussed in Section XIII. The major difficulty encountered relative to automated patching was the equipment size and complexity and cost required in attempting to approach the degree of flexibility afforded by manual patching. A simplified rectangular switching matrix which equals the conventional manual patching equipment in flexibility (any unused point to any other unused point) is directly proportional in size to the square of the number of points to be connected. Also, adding one more point along each side of a matrix which already contains x number of points on a side results in the addition of a total number of 2 x + 1 additional crosspoints. As a result, the cost also increases by approximately the same factor. The efforts documented under Section XIII attempted to optimize switch size and cost by establishing a family of incrementally sized, three stage, space division matrix modules as standard elements and employing links between these modules to obtain a switching complex of reduced size and complexity. As a result, flexibility must be sacrificed; i.e., a certain reduction in capacity and a certain amount of blocking must be accepted. The capacity can be typically 20 percent of the total number of circuit appearances, since this number generally exceeds the number of patches required to be in effect at a given time. The blocking probability can be typically .01 with the switch already activated for 20 percent of the circuits.

An initial application of this approach to the [illegible] site for the equipment arrangement shown by Figure 2, Sheet 1, of Section IV, would result in a complement of switching equipment requiring approximately 120 cabinets and valued at approximately 2.4 million dollars, if implemented with reed relays. It is therefore apparent that even this reduced flexibility switching approach is still not practical. Further efforts to reduce size and cost are obviously in order.

The first approach, mentioned above, employed switch modules, each capable of 512 circuits. For a quantity of approximately 1500 analog circuits (typical of [illegible]), three of these modules would be required. The capability of each switch module is reduced slightly by the requirement for trunking between them. Each 512 circuit switch is, in reality, a configuration of a large number of smaller modular elements. In addition, these elements are arranged to form a three-stage switching matrix. Hence, the first stage consists of 32 individual elements, each being of a 16 x 8 arrangement. The inputs to be switched are connected to the "16" side (16 x 32 = 512 inputs). The third stage consists of 32 individual 8 x 16's, with outputs (to be switched) connected to the "16" side (16 x 32 = 512 outputs). The second stage consists of eight individual 32 x 32 elements providing the trunking between inputs (stage 1) and outputs (stage 3). This configuration, when applied to both the transmit and receive sides of the approximately 1500 circuits, results in a total of 98,304 crosspoints and requires 54 equipment cabinets, just for automation of circuit patching, and not including primary patching, XC patching and group patching.

A more optimum configuration can be obtained by restructuring and employing smaller switch modules (each capable of 64 circuits). In this arrangement the number of modules is obviously increased; i.e., eight modules are required to accommodate the 512 circuits handled by the previously considered switch module (512 circuit module), and 24 modules are required to accommodate the 1500 circuits considered above. In actual design, the 64-circuit module is really larger (e.g., 72 circuits), thereby providing for eight inter-module trunks. Hence, this configuration, when applied to 1500 send and 1500 receive circuits, results in a total of approximately 43,200 crosspoints, and requires approximately 26 equipment cabinets to provide for circuit patching only.

The space requirements of the above configurations forced a further consideration of the utilization of solid state switching elements in lieu of the magnetic latching reed relays considered in the above discussion. The primary advantage of reduced space requirement is considered to outweigh the disadvantages of the solid state switching element. The disadvantages, as indicated in Section XIII, are:

a. Battery required for connectivity

b. Not capable of handling group frequencies

c. Conversion of analog signals to digital required

d. No size reduction for 2-wire circuits

e. Greater power required for crosspoint holding

f. More logic and control circuitry required (Reference Table IX of Section XIII)

The preferred solid state approach (Section XIII) required that the signals be digital for switching purposes, and accomplished digitalization of analog signals via Pulse Width Modulation (PWM). Investigation of design possibilities relative to using this solid state switching element indicates that optimum packaging (greatest space conservation) can be obtained by employing a switch module capable of 96 circuits. Again, 12 of the ports are required for intermodule trunking, leaving only 84 ports for circuit connections. In reality, then, each switch module accommodates 84 circuits. Hence, for the 1500 circuits mentioned previously, a quantity of 18 switch modules are required. Also, three additional switch modules are required to provide intermodule trunking, thus resulting in a total of 21 switch modules (42 for both send and receive). Each switch module is composed of a number of individual smaller modules arranged to form a three-stage switching matrix. In summary, each of the first and third stages consists of a quantity of twelve 8 x 2 matrices, while the second stage consists of a quantity of two 12 x 12 matrices. Therefore, 42 switch modules will result in a total of 28,424 crosspoints, and will require 10-1/2 equipment cabinets. This is an appreciable reduction from the 43,200 crosspoints and the associated 26 cabinets required for the reed relay approach.

The quantities of crosspoints and of equipment cabinets as established above are those required to provide for circuit patching of a quantity of 1500 VF channels. This is the quantity of channels existing at the Fuchu site, which is considered to be one of the largest stations. Upon closer examination of the actual usage of the circuits, and taking into account the cost (approximately $10 per crosspoint) of the required switching, it becomes apparent that it would not be technically effective, nor cost-effective, to provide switching for all circuits. Investigation reveals that of the approximately 1500 total VF circuits, at least 450 are switched trunks terminated on the collocated tandem switch. Such channels are selected by the tandem switch providing automated patching (switching) at the circuit level, while the ATECF is effectively duplicating an

existing capability. Also, of the approximately 1500 circuits mentioned above, about 75 to 80 are AUTOVON trunks connected to the collocated AUTOVON switch. These circuits are segmented into small groups at the ATECF circuit patch/switch, and require only a limited switching capability at this point. Hence, of the 1500 circuits only about 1000 need be provided with switching capability at the ATECF circuit/patch/switch. For this reduced number of circuits, the above solid state switching approach reduces to approximately 19,000 crosspoints, requiring seven equipment cabinets. It should be noted that a separate additional cabinet is needed for the required switch controller.

The solid state matrix approach to the circuit switch, as described above, is considered to be near optimum. However, it is still relatively costly, nearly \$200,000 (at an estimated \$10 per crosspoint), and requires a total of eight cabinets. It also requires a major additional item for support, namely, a storage battery capable of maintaining all activated connections during a major power failure. The actual switching requirements could be further reduced, however, by providing switching for only selected circuits, that is, for only high priority circuits or for circuits selected on some other restricted basis.

A careful examination of the other candidate areas (patch bays) for application of automated patching has been accomplished with the objective being to minimize switching requirements. Consideration was first given to the ATECF primary patch. This patch facility is, in most cases, nearly as large as the circuit patch, and would thus require a comparable switching complex. However, the function of the primary patch is primarily that of equipment substitution. That is, when used in conjunction with the circuit patch, a spare or preempted line conditioning equipment can be substituted for a failed unit, or inserted into a channel when deemed necessary. It should be noted, though, that only certain combinations of line conditioning equipments and VF channels are permissible; therefore, complete interconnection capability is unwarranted for this purpose. Hence, it would suffice to group channels according to line conditioning requirements and to provide switching capability so that one or more spares of like conditioning equipments could be connected to a channel (of the group) when and as required. This would greatly reduce the switching requirement, and would, in fact, result in a configuration equal to about one-fourth the size and cost of the circuit switching configuration. However, further investigation reveals that the line conditioning equipments have relatively low failure rates; hence, the rate of substitution for this purpose is very low. It was therefore concluded that automated patching (switching) would not be cost effective, and should not be provided for the ATECF primary patch.

Consideration was next given to the ATEC facility DC patching requirements. The DC patch bay provides access to DC circuits, and as such provides a function for DC circuits similar to that provided for VF circuits by the circuit patch bay. The frequency of patching at the DC patch bay, however, is much greater than at the circuit patch bay. This is due primarily to the requirement for greater quality relative to digital traffic. That is, minor degradations in transmission quality which in a voice message are smoothed out by the human ear will appear as message errors in digital traffic. Also, the greater number of equipments involved in digital communications (modems, VFCT, regenerators, etc.) to derive digital channels from voice channels, as well as the greater prevalence of encrypted traffic (and associated equipments) on digital circuits, will result in a greater need for DC patching. Therefore, if switching is considered for circuit patching, it should be given even greater consideration for DC patching. It is recommended that first preference be given to automated DC patching. Relating this requirement to the Fuchu site, it was determined that a capability for DC patching be provided for about 700 DC circuits. This is considered to be the largest site requirement. The approach to switching for the DC patch is the same as that for the circuit patch except that no modulators or demodulators are required, since the signals are already digital. It is necessary, however, to provide a converter module for each output of the switch in order that signals coming out of the switch will again be low level, in accordance with MIL-STD-188B. The low level input to the switch will be accepted directly. In order to provide switching for all 700 DC circuits, a total of about 13,300 crosspoints are required ($133,000), in 4-1/2 cabinets plus a switch controller cabinet. Again, as in the case of the circuit patch, this switching requirement can be further reduced by providing switching only for selected circuits (high priority, special circuits, etc.).

The requirement for group switching was considered last, primarily because it is somewhat different from the other requirements. The major points of concern are the high signal frequencies and the low signal levels inherent in group patching. The potential for intermod distortion and crosstalk problems, as a result of using solid state switching elements, establishes a high preference for the reed relay for this application, in spite of its inherent increased space requirement. The fact that two types of switching elements will then exist within an ATEC facility is of lesser importance than the requirement for technically effective and cost-effective system design. If the requirements of the Fuchu site are again considered, it is found that approximately 100 groups are available for switching. Considering the original reed relay matrices of 64, 128, 256 and 512 ports, the 128 port unit is appropriate. Recalling that this matrix is a three-stage matrix wherein stages 1 and 3 are each composed of sixteen 8 x 2's and stage 2 is composed of [illegible], it is found that a total of 2048 crosspoints, requiring three cabinets, are needed. The fallacy of this approach is that it does not take into account the specific configuration of the group patching requirements. That is, five groups make up a supergroup, and any group should be

switchable to any other group within its associated supergroup or within any other supergroup. The supergroups may be within a single baseband or distributed among several other basebands. A more technically effective switching configuration for 110 groups would be a three-stage 110 port matrix. Stage 1 would consist of 11 individual 10 x 4 matrices, stage 2 would consist of four individual 11 x 11 matrices, and stage 3 would consist of 11 individual 4 x 10 matrices. The result is 2728 crosspoints requiring three cabinets. This is somewhat more than the 2048 crosspoints (approximately $7000 additional) contained in the previous configuration, which employed the 128 port matrix. The improvement in capability, however, is significant. The amount of blocking has been nearly halved, and compatibility is considerably improved.

High priority channels are expected to be grouped or concentrated. That is, all highest priority channels within a given baseband are to be located within a single group (one or more additional groups may be required, depending on the number of channels); hence, upon failure of group equipment, a lower priority group may be preempted to support the higher priority group. Similarly, where link degradation is experienced, the lower priority groups may be dropped and only the highest priority groups retained. The switch configuration described above specifically provides for this capability. That is, the individual 10 x 4 matrices provide terminations for the 10 groups that make up two supergroups, and permit the connection of up to four of these groups (two from each supergroup, four from one supergroup, etc.) to four other group channels. In addition, manual patching at the group level is still retained in order to provide back-up in the event of switch failure, and to handle the overload in the case of mass failures.

The applicability of switching to both supergroup and baseband patching was also considered. Since the number of supergroups and basebands at a given site is relatively small, the required switch could also be relatively small. However, the advantages to be gained from the implementation of switching at these points would be primarily restricted to patching speed. The other advantages mentioned previously would be of less importance at these points because of their small number and simple patching configuration. Even if switching were desired, a major deterrent exists, which precludes its cost effective and even technically effective implementation. This deterrent exists because accommodating (via switching) the high frequencies and low levels associated with the communications signals at these points is not readily accomplished. In addition, the loading effects caused by the introduction of switching at these points can cause serious degradation of the normal communications signals. These problems contribute to a very high-cost switching for supergroup and baseband switching. Therefore, it is recommended that switching not be implemented at these points because of the technical and cost problems, as well as the minimum gains to be obtained. Instead, efforts and funds should be concentrated on improving patching.

3.2.2 General

There are four patching facilities required for ATEC: group, circuit, primary and digital (DC). By design there is considerable commonality of functions and hardware throughout the four facilities. In this paragraph, the major functions will be described first, to establish definition and understanding, prior to the facility configuration discussions. The principal characteristics of the switching and patching facilities are outlined briefly below, not necessarily in any order of importance.

3.2.2.1 Sealed Contact Jacks

Sealed reed relays will replace the open point normal-through contacts used in conventional jacks. These relays will not be an integral part of the jack, but will be actuated by control signals generated by patch cord insertion. The only open contact surfaces will be between the plug and jack surfaces (tip and ring). This concept of manual patching will substantially reduce the system noise generated by dirty and corroded normal-through contacts.

3.2.2.2 Cord Scanning

Insertion of a cord into a jack will generate a level which will be sensed electronically through a solid state cord scanner. This scanner will deliver cord insertion and removal data to the ATEC processor to aid the Tech Controller when manual patching must be resorted to. Every jack in the ATEC patching facilities is to be afforded electronic cord scanning.

3.2.2.3 Normal-Through Connections

Every normal line-side to equipment-side through-connection will be completed through a reed relay. This relay is actuated through local matrix control by processor-generated patching instructions.

3.2.2.4 Monitor/Test Connections

Several monitor and test trunks are bused to all 2-wire circuits. A monitor trunk, with its associated high impedance test device, is bridged across the circuit to be monitored when the selected reed relay crosspoint is operated. A test trunk opens and terminates the circuit when the reed relay crosspoint is operated. A test trunk can be used to inject test signals, such as tone or "FOX," into many circuits simultaneously.

3.2.2.5 Solid State Patching Matrix

A processor directed space division matrix will effect line side to equipment side patches to any one or more two wire circuits. The send and receive pairs of a typical 4-wire circuit can be switched independently. Since the matrix crosspoints are digital (a 4-crosspoint MSIC is used) voice band analog circuits are digitized at the input and reconstituted at the output. Digital signals need only be level converted (up or down) in order to be switched. The three-stage matrix can be optimized for a statistical number of simultaneous patches that it can sustain at a specified probability of blocking. Blocked patches are then put up manually.

3.2.2.6 Reed Relay Group Patching

Because of the bandwidth involved the group signals cannot be switched through a digital solid state matrix. Therefore, a reed relay matrix will be employed to provide a comparable processor directed patching service for group signals.

3.2.2.7 Relay Hardware in Patch Bays

The relays for the normal-through and monitor/test connections will be mounted on printed wiring boards. These boards will in turn be mounted in the same cabinets as the jacks with which they are associated. The average cabinet will contain jack sets and relay boards for 120, 4-wire circuits.

3.2.2.8 Switching Matrix Blocks

The basic building block for the solid state patching matrix will switch up to 96 circuits. Printed wiring boards can be deleted to the extent necessary to equip the matrix downward for less than 96 circuits. Up to six blocks can be grouped in a cluster, with a seventh block serving as the point of interconnection between the blocks. Two or more clusters may be trunked together to establish a facility in excess of 1000 circuits, or to create a "split patch facility." Four 96-line blocks will be contained in one matrix cabinet.

3.2.2.9 Group Matrix Equipment

To minimize wire lengths and stubs, the group switching relay boards will be mounted in the same cabinet/rack with the mux and channel equipment. This switch will be partitioned into small blocks appropriate to each cabinet, with limited trunking between cabinets.

3.2.3 Switching Functions

3.2.3.1 Jacks and Normal-Through

The method for utilizing reed relays to replace open contacts on the jacks in shown in Figure 7. Relay K1S will open when a DC control circuit is completed through the cord sleeve to the equipment side jack of another send circuit. The comparable relay (K5S) of the other send circuit will also open. While K1S is open it terminates the circuit coming from the right. K5S operates in like manner when a cord is plugged into the line side of another send circuit. The same arrangement works between receive circuits. Cords are patched between the line and equipment sides of different circuits, and L to L or E to E on the same circuit for a loop-back.

Relay K3 is the normal through contact, and is remotely (processor) controlled. Relays K2 and K4, also remotely controlled, provide access to the switching matrix. To patch the receive circuit through the matrix to another termination, the ATEC processor first directs the local switch control to close K2R. This action automatically opens K3R at the same time. If a 4-wire patch is being implemented, K2S is also closed, causing K3S to be opened. K3 is interlocked so that it must open when either K2 or K4 is closed. While K3 is open the two legs of the circuit are each terminated in the solid state patching matrix. K2, K3 and K4 are magnetic latching and are, therefore, pulsed open and pulsed closed - no holding current.

Relay K6 provides a way for the processor to put up a send to receive loop-back patch within a 4-wire circuit. The K2 and K3 relays must be opened before closing K6. By placing K6 between K1 and K5 the relay loop-back can be bypassed by any line side cord patch. A send to receive cord patch is also possible because of the polarities on the coils of K1S and K1R.

3.2.3.2 Monitor and Test Trunks

The utilization of reed relays for the monitor and test functions is illustrated in Figure 8. Two typical trunks are shown. These relays are magnetic latching, and are pulsed open and pulsed closed through the local matrix control from remotely generated monitor and test instructions. A test trunk can be connected to many lines at once for the prupose of injecting a common test signal, such as "FOX" or a standard tone. The number of simultaneous connections is limited not by the switch but by the drive impedance of the test signal source. When a test connection is made, a substitute load impedance is switched in to terminate the source.

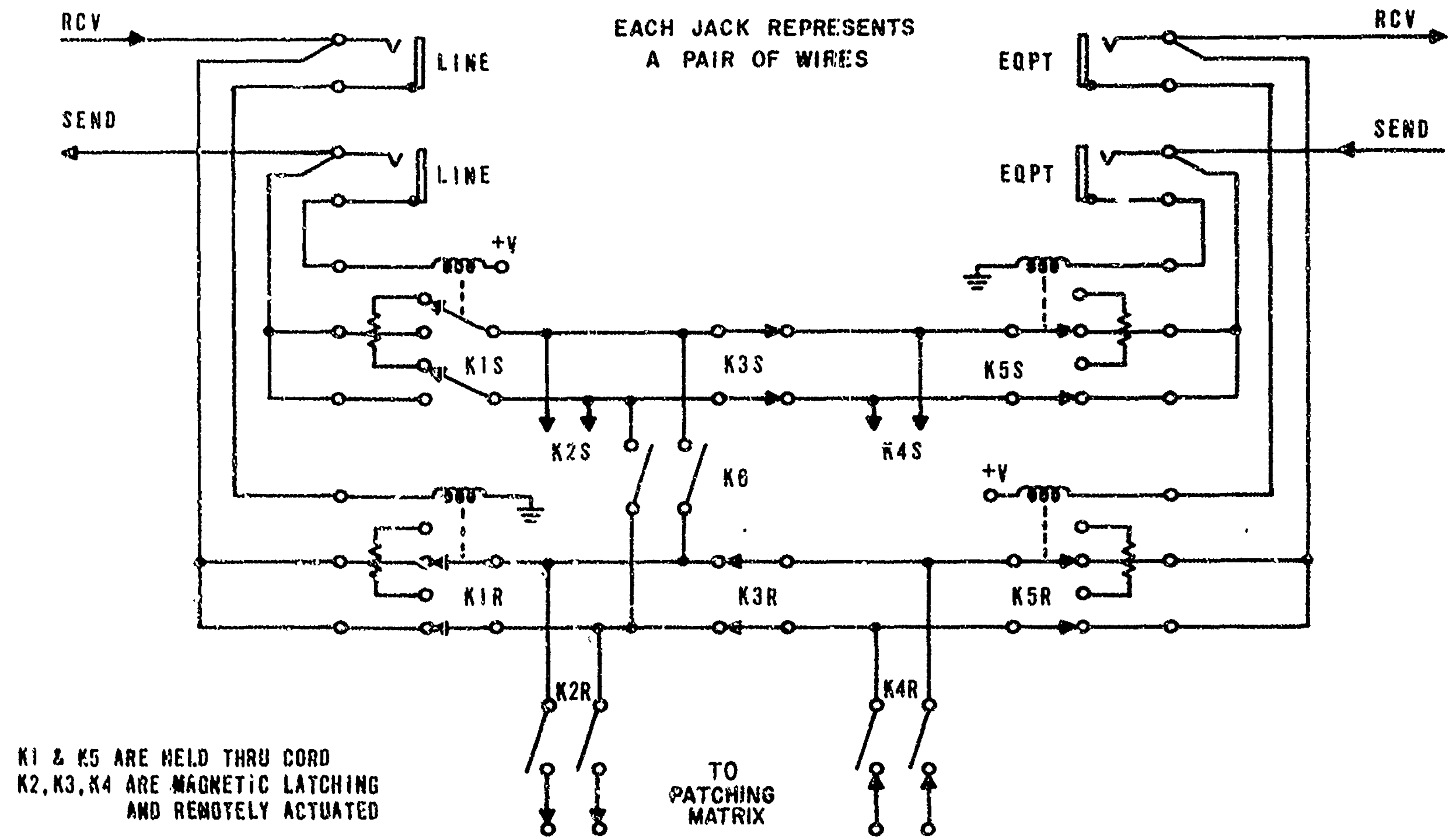


FIGURE 7 JACK & NORMAL-THRU CONNECTIONS

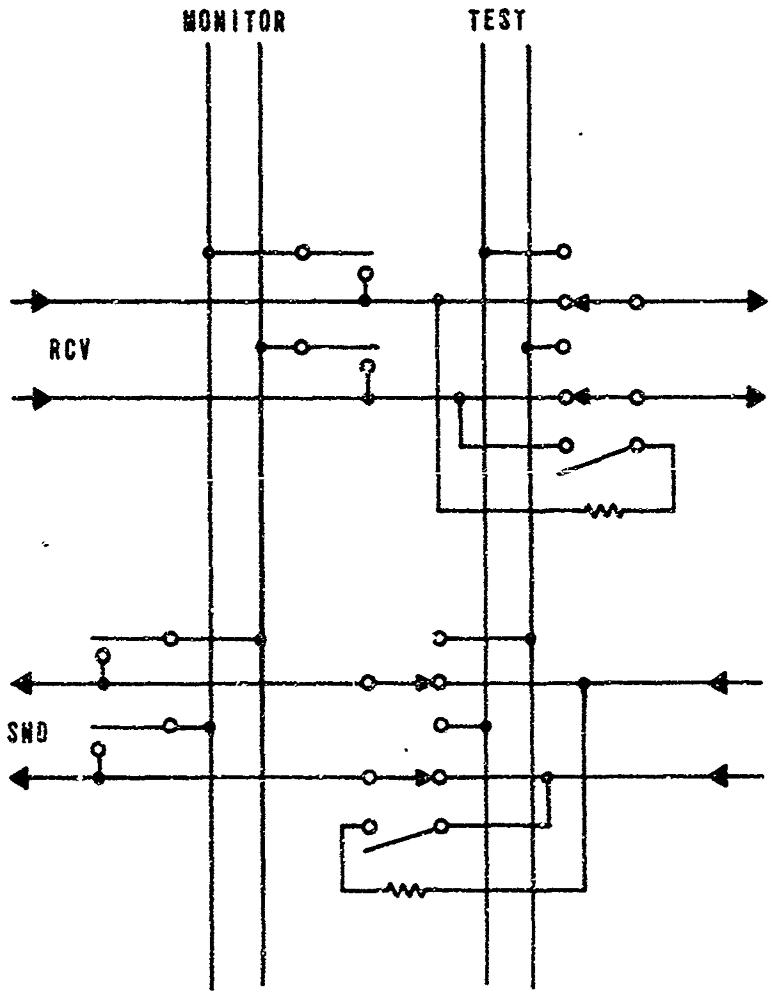


FIGURE 8 MONITOR & TEST TRUNK CONNECTIONS

3.2.3.3 Cord Scanner

The K1 and K5 relays (see Figure 9) contain a control contact not shown in the diagram, omitted for graphic clarity; and because the same function may be accomplished by an auxiliary contact on the jack itself. When the relay is actuated this contact closes ground to an integrated circuit multiplexer. The multiplexer is commutated periodically by the cord scanner common control. This control recognizes when a cord is inserted or removed, and forwards this information to the ATEC processor. In an alternate mode the scanner will continually inspect only those jacks for which it has received addresses from the processor. The processors utilize the scanner returns to inform the Tech Controller, through his display console, that directed manual patches have been properly executed. An integrated circuit for scanning is included on every relay board containing K1 and K5 relays. The cord scanner is diagramed in Figure 9.

3.2.3.4 Relay Control

The relay switching functions are controlled separately and independently from the patching switches (including the group switch, even though it is relay). There are three reasons for this separation:

a. The methods of crosspoint actuation are substantially different, so that little efficiency is gained by combining the relay and solid state switching control logic.

b. Not all circuits will be afforded switched patching; but all circuits will be equipped for automatic monitoring and testing.

c. Failure in the more complex patching matrix will not compromise the much more frequently used relay control logic.

The control logic receives from the processor an instruction that identifies the specific 2-wire circuit plus the specific monitor/test trunk or normal through function (K2, K3 or K4). For control purposes all the relays are arranged in an X-Y coordinate array. Using the instruction's open or close directive, the control logic selects an X driver and a Y driver. These drivers are pulsed for 5ms, and the relay at their intersection is actuated. Concurrently, verification signals are picked up through a separate network to tell the control whether or not the selected relay was actuated. Each relay contains an extra contact for this purpose. When actuation is complete, the control logic forwards a yes or no verification response to the processor.

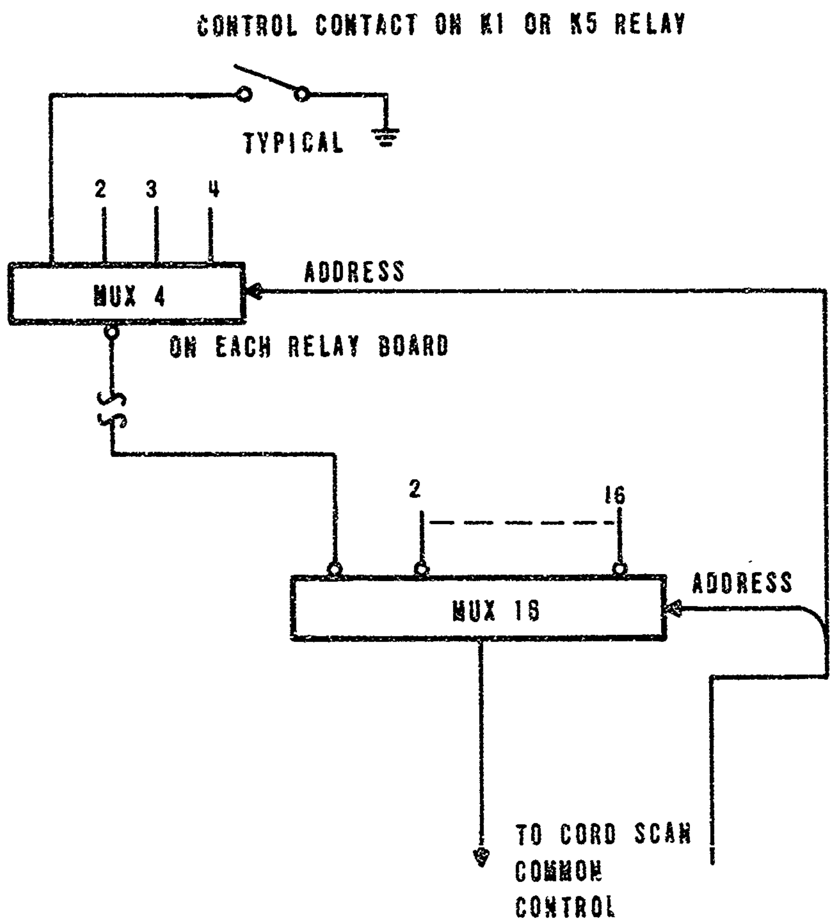


FIGURE 9 CORD SCANNING

3.2.3.5 Scanner Control

The scanner common control distributes line address signals for commutation, and collects and formats the multiplexed responses. Upon direction from the ATEC processor, the scanner will commutate all lines periodically, or concentrate on a very few selected lines. The latter mode would be chosen after a manual patch has been ordered so that the Technical Controller can check upon the timely and accurate implementation of his orders. Scanner control is separate from and independent of the relay and patching matrix control logics. This is done because the logic is substantially different, and because the scanner is most needed at times when extensive manual patching is required. Therefore, failure of the switching control logic, or its use to troubleshoot the crosspoints, should not compromise the cord scanner operation.

3.2.3.6 Solid State Patching Switch

The patching switch provides a limited number of electronic patchcords. Its internal modularity permits the switch to be equipped for a quantity of electronic patchcords equal to the average number of regular cords that one could expect to see up at any time in a conventional patch facility. The basic element of this switch is an MSIC containing four bi-directional digital crosspoints and their supporting selection and latching logic. These elements, which are actually little 2 x 2 matrices, are arranged on printed wiring boards into larger submatrices. These submatrices are in turn interwired to form the basic matrix block of 96 terminations. When the send and receive sides of a 4-wire circuit can be switched together, one block can be used to switch up to 96 4-wire terminations. But if separate control of send and receive is necessary, then two independent blocks must be used, with the crosspoint circuits not fully utilized.

When the switch is incorporated in the circuit patch facility, the voice or modem signal at each inlet is digitized by a pulse width modulator circuit. The digitized signal is switched through the integrated circuit crosspoints - no less than three, and as many as twelve - for an intercluster connection. At the outlet the digital signal is integrated in a demodulating circuit to recover the analog waveform. In the DC patch facility the pulsewidth mod-demod circuits are unnecessary because the signals are already digital. Since the in-station DC signals will conform with the MIL-STD-188B, the matrix terminations will be equipped with 188B compatible interfacing circuits.

The arrangement of 96 line blocks into clusters is illustrated in Figure 10. In the typical configuration shown, twelve of the 96 terminations serve as intracluster trunks. The common block serving these trunks is

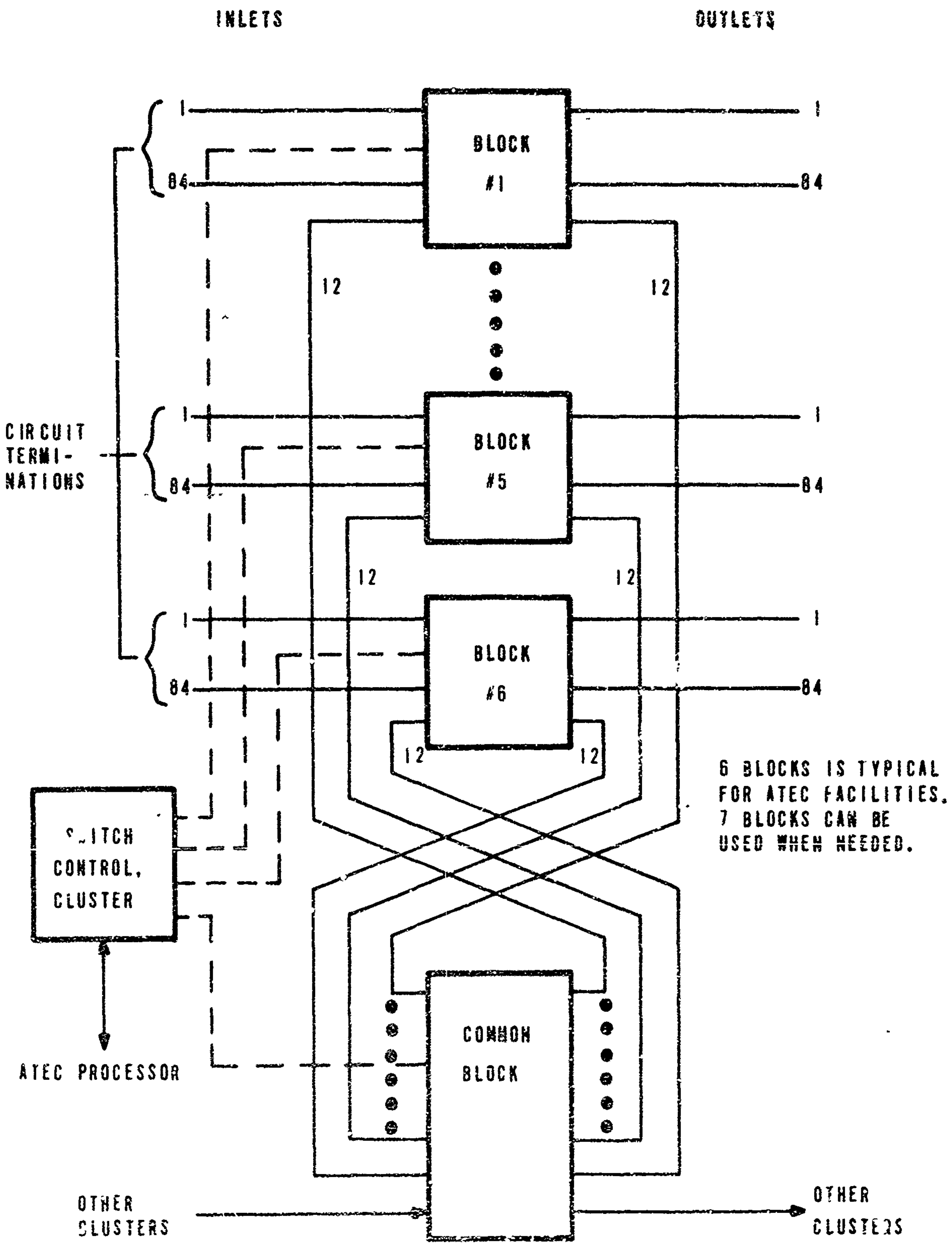


FIGURE 10 SOLID STATE PATCHING MATRIX
FOR CIRCUIT AND DC PATCHING

identical to the other blocks, but it does not need to be equipped with pulse width mod-demod circuits or MIL-STD 188B circuits. As shown, the cluster can serve up to 588 circuits (7 x 84). By deleting blocks, any lower number of circuits can be efficiently served. The most practical cluster for ATEC purposes is a 6 + 1 block configuration, providing 504 circuit terminations (6 x 84) and 12 interconnect trunks in each block. The cluster is limited to eight blocks due to the practical aspects of control. But if two identical clusters are needed to provide independent send and receive switching, one common cluster control can serve all blocks (up to 16). As part of the facility engineering task, circuits are assigned to matrix terminations so as to minimize, statistically, the number of interblock and intercluster connections. This minimizing will result in fewer blocked patches and more efficient utilization of switching hardware.

3.2.3.7 Patching Switch Control

In order to execute an electronic patch, the ATEC processor must forward to the switch/cluster control logic the binary address of the two terminations to be connected (or disconnected) in a given block. Local control then searches for an internal path, selects and actuates the solid state crosspoints, verifies through an independent network that the selected crosspoints were in fact actuated, and forwards a yes or no response to the processor. If no internal path could be found, a "blocked patch" response is returned. Interblock connections require three separate instructions, and the processor must keep track of the usage of interblock trunks. The total time for the switch to recognize, execute, verify and respond is approximately 30 microseconds. The control logic interfaces with the ATEC processor through an input-output channel with 16 data bits in each direction plus associated strobes.

The group switch control is functionally very similar to the circuit DC patching switch control described above. The interface with the processor is the same, and the same type of instruction and response is employed. Because the crosspoints are relays, the method of actuation is much more like the X-Y relay control (see subparagraph 3.2.3.4), than the solid state control. An internal patch search is not necessary because the blocks in the group switch are small enough to be non-blocking square arrays.

3.2.4 Patch Facility Configurations

With the preceding component and function descriptions serving as background, this section will describe the four patch facilities, with the aid of diagrams.

3.2.4.1 Circuit Patch

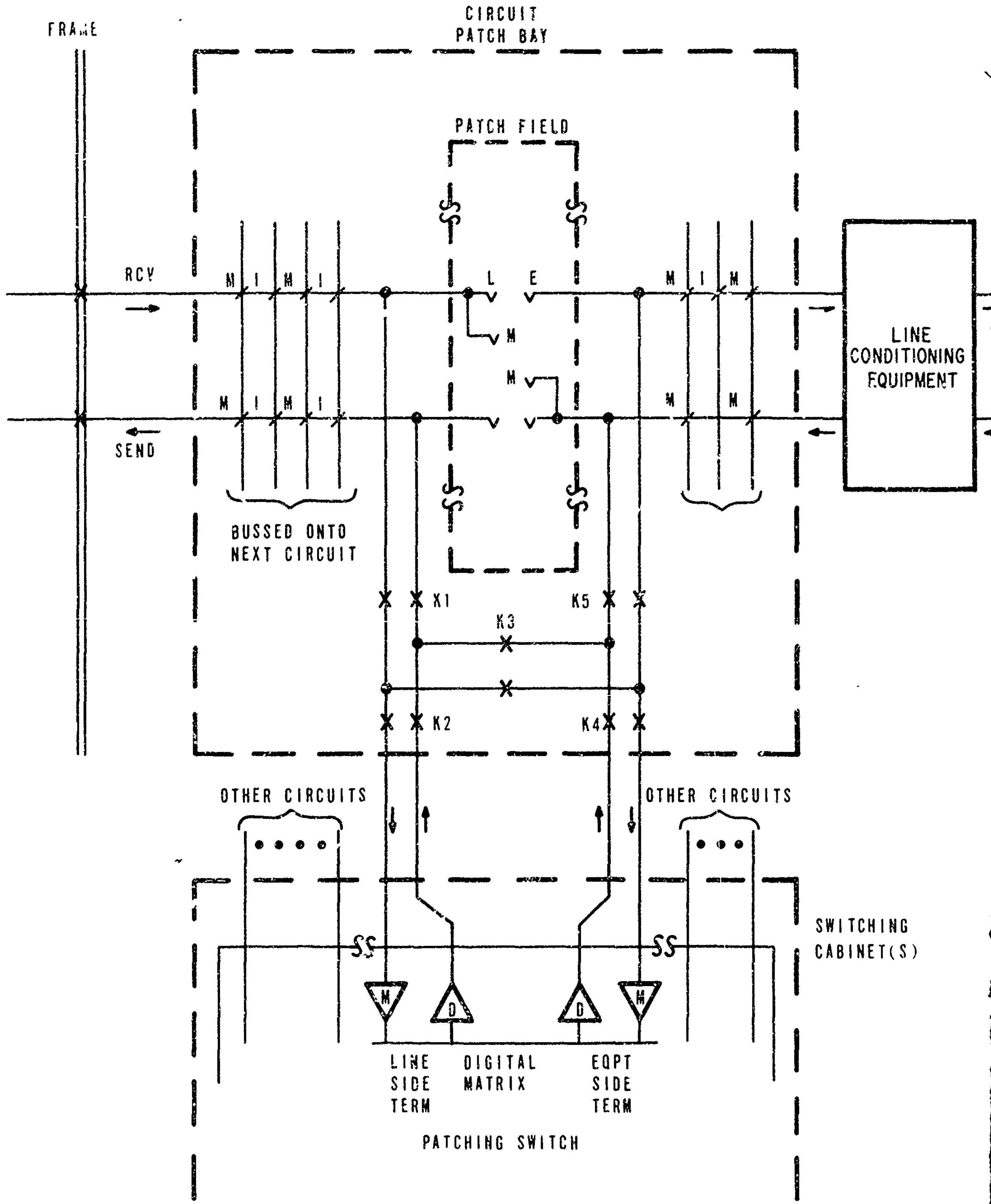
The circuit patch facility is illustrated on the left side of Figure 11 showing one typical 4-wire circuit. This circuit can also be treated as two independent, oppositely-directed 2-wire circuits. The patch bay can function without the patching switch, and indeed is quite likely to at a small ATEC center where the cost of electronic patching is not justified. Furthermore, not all circuits that pass through the patch bay need to be routed to the switch as well: selected circuits of low priority and/or usage can be patched only by manual means. The switch however, cannot function without the patch bay, since the relays therein (K2 and K4) route the circuits to the switch. Electronic patches are constrained to L-to-E send, L-to-E receive, and L-to-L loopbacks. The monitor and test trunks are routed to consoles as shown in the illustration. Reasons for selecting the particular configuration of monitor and test trunks are given in paragraph 3.2.5 of this section.

3.2.4.2 Primary Patch

The primary patch facility is illustrated on the right side of Figure 11 It is used in conjunction with the circuit patch to provide manual patching of line conditioning equipment and to provide an automatic monitor and test capability on both line and equipment sides. Since conditioning equipment is not electrically patched, there is no need for the remotely controlled relays (K2, K3, and K4). The typical circuit shown is 4-wire, but, where necessary, it can be treated as two 2-wire circuits. This would also be the case when 6 or 8-wire circuits are to be patched; the signals in excess of the send and receive pairs are patched through adjacent 2-wire paths, thereby reducing the total number of circuits that a primary patch bay of a given size can handle. Reasons for selecting the particular configuration of monitor and test trunks are given in paragraph 3.2.5.

3.2.4.3 Digital (DC) Patch

The configuration of the DC patch is very similar to the circuit patch (See Figure 11). A significant difference is that the typical MIL-STD 188B low level DC circuit is one-wire single ended with a carefully controlled common ground return. This signal is carried through the jacks on the tip. This characteristic makes no difference to the digital patching matrix, because it switches all signals single ended. Since DC send and receive may have to be switched independently, separate matrix paths through the matrix must be provided, and one direction of the crosspoint circuit will not be utilized. Some digital signals are, however, accompanied by a clock signal, such as that which is associated with a modem. When this clock moves in the opposite direction of the data, as in the transmit side, the otherwise unused path through the digital crosspoint can be employed because the signal and clock are switched together. If clock and data move in the same direction, as in the receive side, a parallel matrix path must be employed. The clock signals are carried through the jacks on the ring.



FRAME
CIRCUIT
PATCH BAY
PATCH FIELD
RCV
SEND
M I M I
L E
M
M
M I M
BUSSED ONTO
NEXT CIRCUIT
LINE
CONDITIONING
EQUIPMENT
K1
K5
K3
K2
K4
OTHER CIRCUITS
OTHER CIRCUITS
SWITCHING
CABINET(S)
M
D
D
M
LINE
SIDE
TERM
DIGITAL
MATRIX
EQPT
SIDE
TERM
PATCHING SWITCH

A

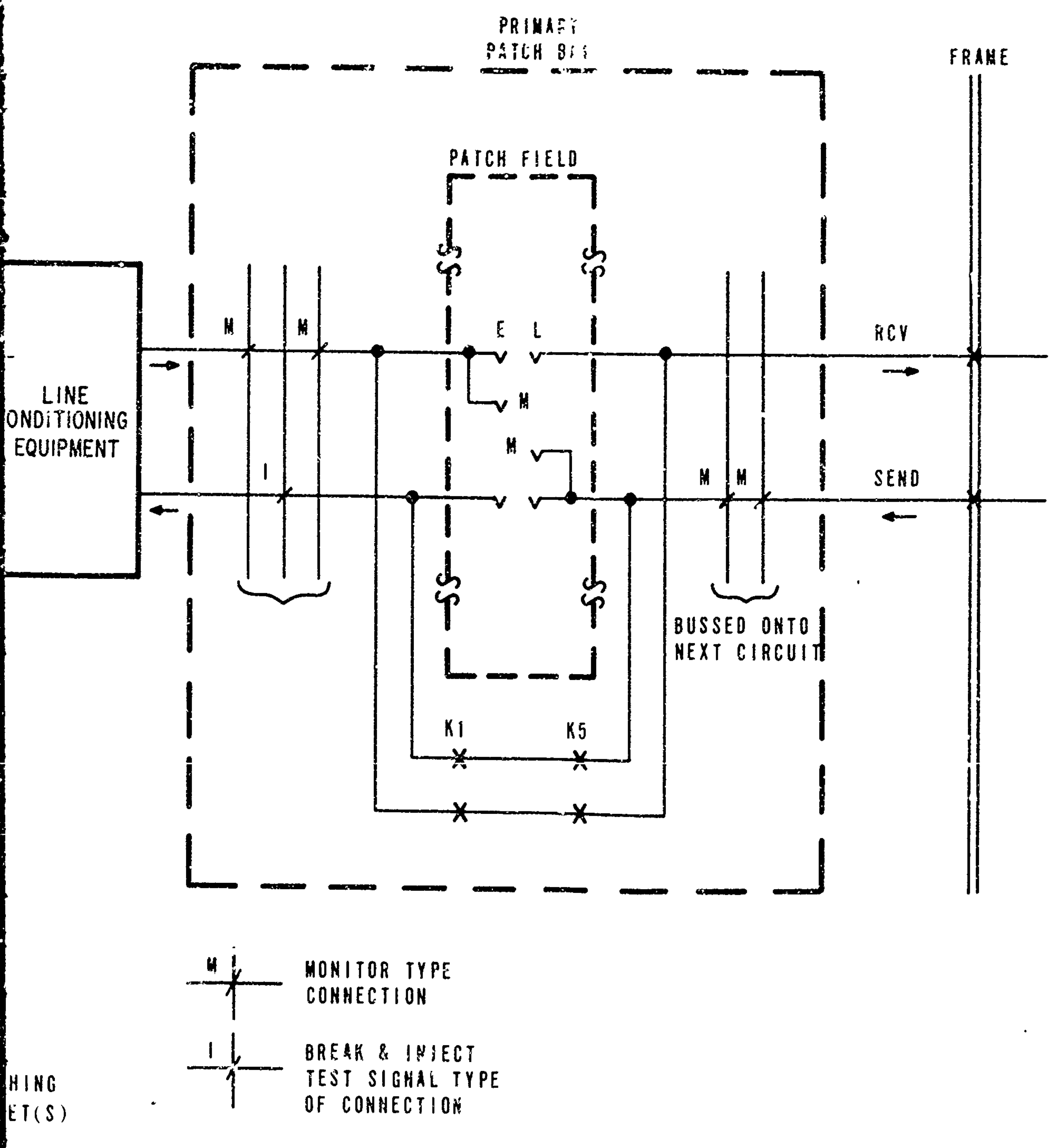


FIGURE 11 ATEC CIRCUIT PATCH FACILITY AND PRIMARY PATCH FACILITY

B

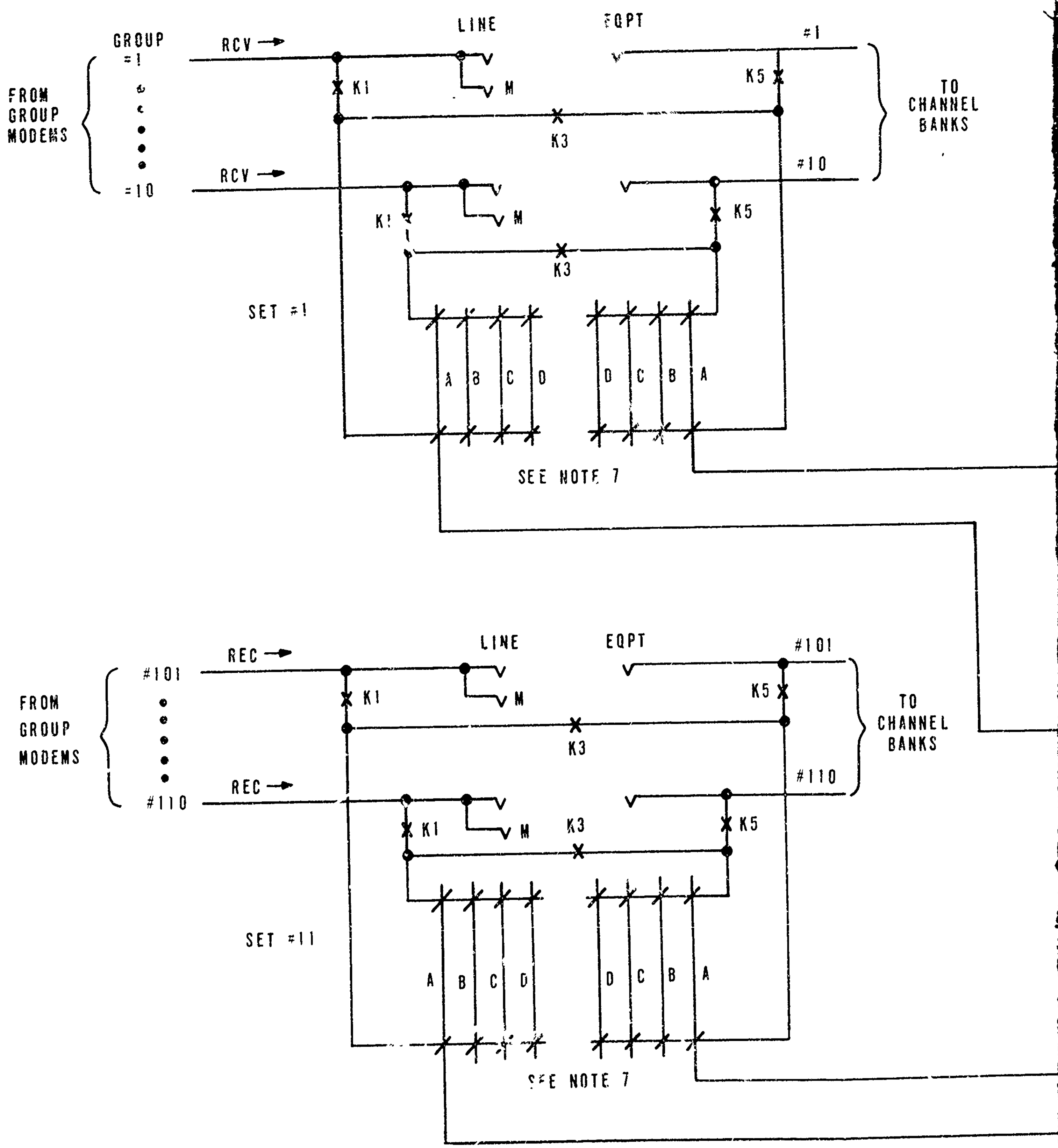
To maintain standard hardware the relays in the DC patch bay will be 2-wire as in the other facilities. So when a block is present, a complete path through the patchbay already exists. The monitor and test trunks also operate in a single ended mode, and are integrated into the controlled ground return system. Send circuit termination will be biased to present a mark hold level to the circuit. The trunks are actually 2-wires, as in other facilities; so the clock signal can also be monitored and tested along with the digital data signal. Reasons for selecting the particular configuration of monitor and test trunks are given above in paragraph 3.2.5.

3.2.4.4 Group Patch

A typical receive group patching and switching configuration is illustrated in Figure 12. Multiplex receive groups are arranged into sets of 10; two typical sets are depicted. These sets are interconnected by links such that the line side of any one group can be connected to the equipment side of any other group, and equipment to line as well. There may be any number of sets of groups up to 160; the figure is shown for one of the largest anticipated facilities. The K1, K3, and K5 relays function the same as in the other patching and switching facilities. Relay functions K2 and K4 are merged into the relay switching matrix. Send and receive sides are switched independently through identical 2-wire matrices; the receive matrix, shown in the figure, is therefore identical in all respects to the send matrix which is not shown. Both matrices are actuated from the same common control unit. Because the switch is a three stage array with limited inter-stage trunking, there is a finite probability of blocking during periods of extensive patching.

Because of the group frequency band, it is desirable to place the switching hardware as close to the group mux-demux and channel equipment as possible. Consequently, one complete 10 group submatrix set, along with the associated patch panels, and local control, will be packaged in a 19 inch rack mounting assembly. This assembly can be installed in the same rack as the channel and modem equipment it serves, if space is available. The signal interface out of this assembly consists only of the interconnect trunks A, B, C and D. The interconnect submatrices, plus the common control logic, will be contained in a separate nearby cabinet. Two master groups, each with its own power supplies (for redundancy) will be contained in one cabinet. The control and matrix hardware is modular, and can be equipped downward for less than 160 groups, in increments of five groups (usually one supergroup).

Automatic send-receive patching in one group is not provided, primarily due to the problem of connecting group-through filters into the loopback. Monitor and test trunks are not included for reasons given in paragraph 3.2.5.


GROUP
=1
=10
FROM
GROUP
MODEMS
RCV
RCV
LINE
EQPT
M
M
K1
K1
K3
K3
K5
K5
#1
#10
TO
CHANNEL
BANKS
SET #1
A
B
C
D
D
C
B
A
SEE NOTE 7
#101
#110
FROM
GROUP
MODEMS
REC
REC
LINE
EQPT
M
M
K1
K1
K3
K3
K5
K5
#101
#110
TO
CHANNEL
BANKS
SET #11
A
B
C
D
D
C
B
A
SEE NOTE 7

NOTES:

1. ALL GRAPHIC LINES REPRESENT 2 WIRE CIRCUITS.
2. K1 & K5 RELAYS ARE NON MAGNETIC LATCHING.
3. ALL OTHER RELAYS ARE 2 POLE MAGNETIC LATCHING.
4. SWITCH PATCH EQUIPMENT FOR ONE 10 GROUP SET IS LOCATED IN MODEM & CHANNEL EQUIPMENT RACKS.
5. INTERCONNECT SUBMATRICES ARE LOCATED IN NEARBY CABINET ALONG WITH CONTROL.
6. SEND AND RECEIVE MATRICES ARE INDEPENDENTLY CONTROLLED.
7. LINKS B, C, D CONNECT TO INTERCONNECT SUBMATRICES B, C, D, RESPECTIVELY

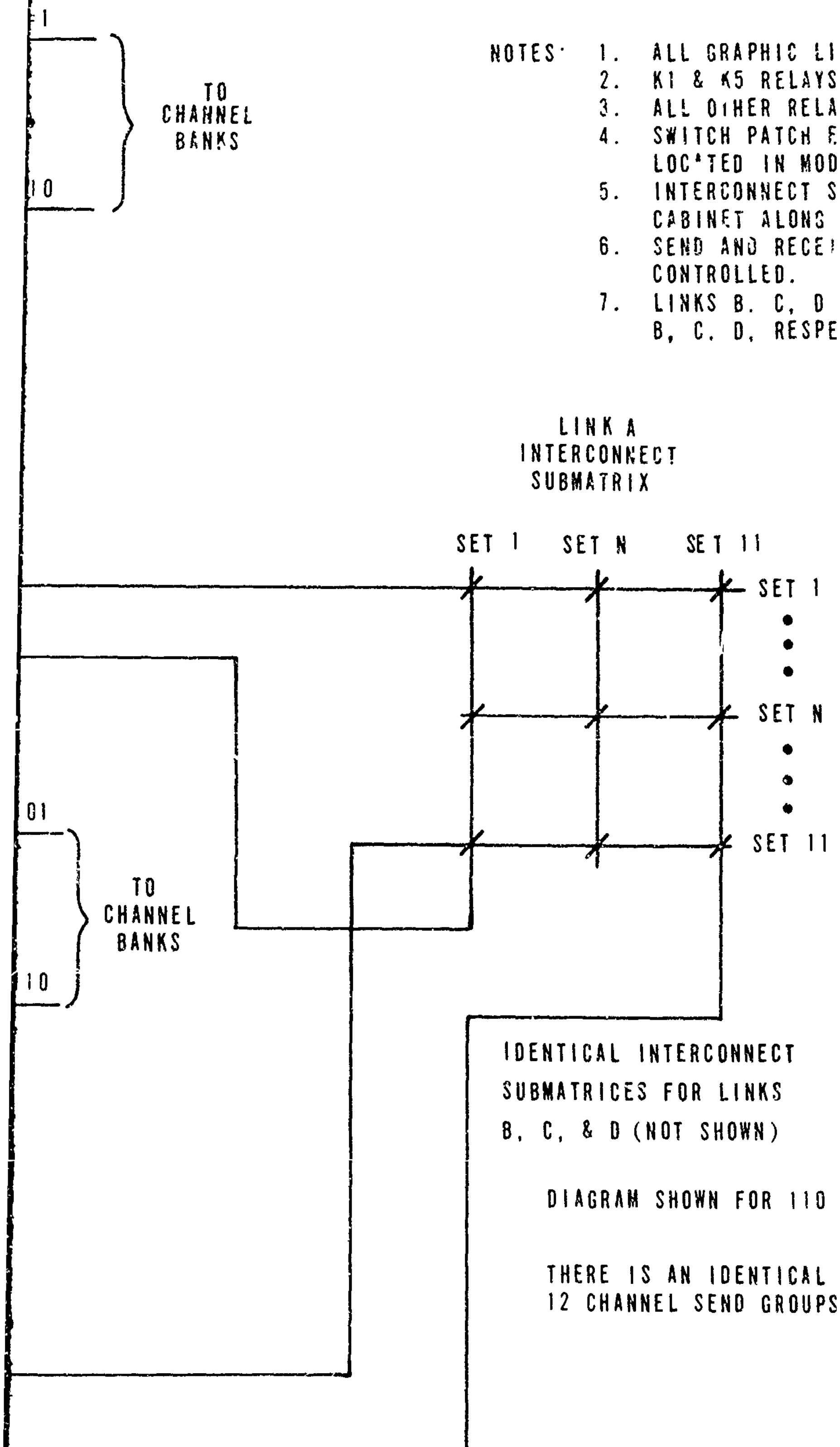


DIAGRAM SHOWN FOR 110 EACH 12 CHANNEL RECEIVE GROUPS

THERE IS AN IDENTICAL PARALLEL MATRIX FOR 110 EACH 12 CHANNEL SEND GROUPS.

FIGURE 12 TYPICAL GROUP PATCHING AND SWITCHING FACILITY

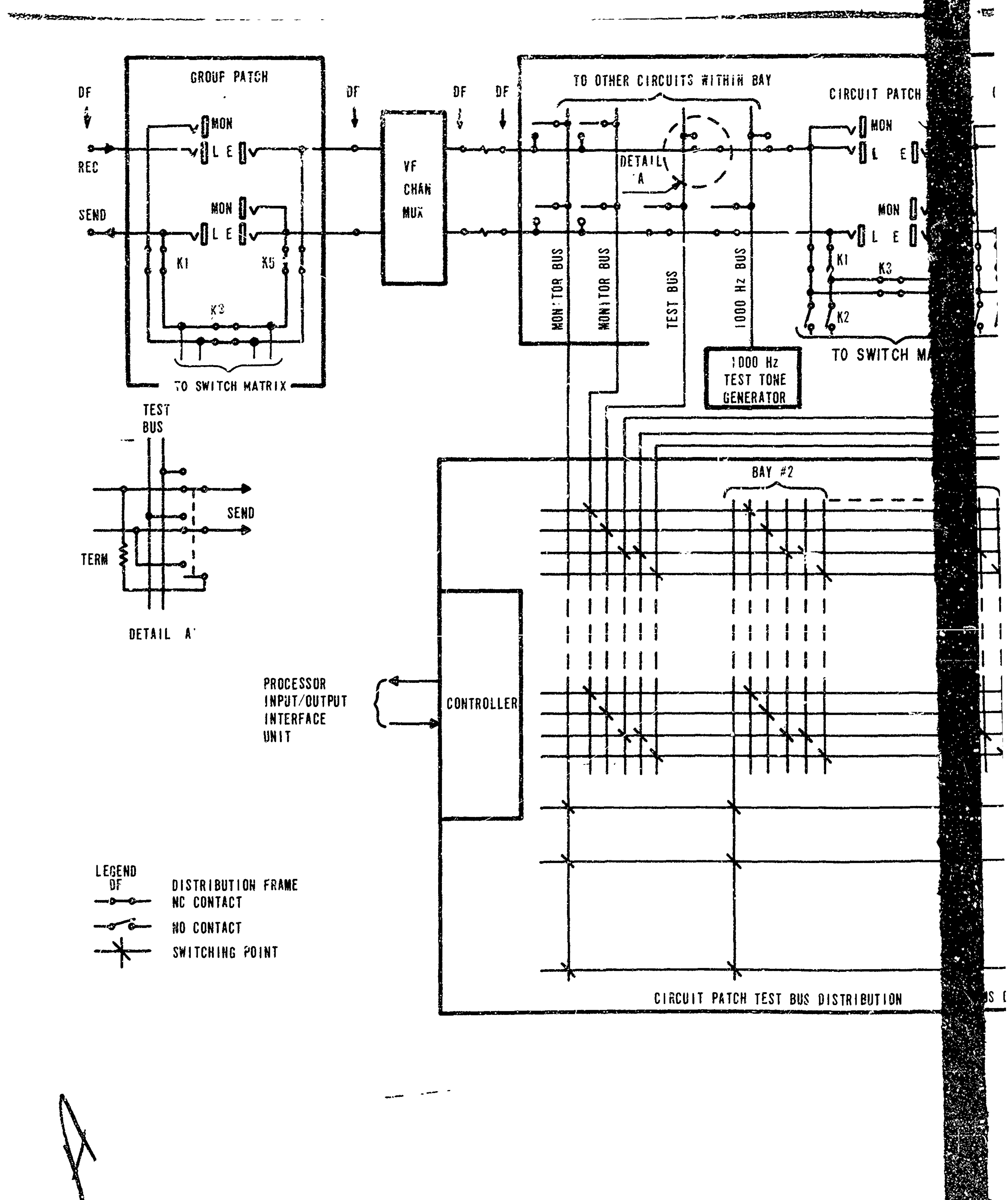
3.2.5 Test Bus Configuration

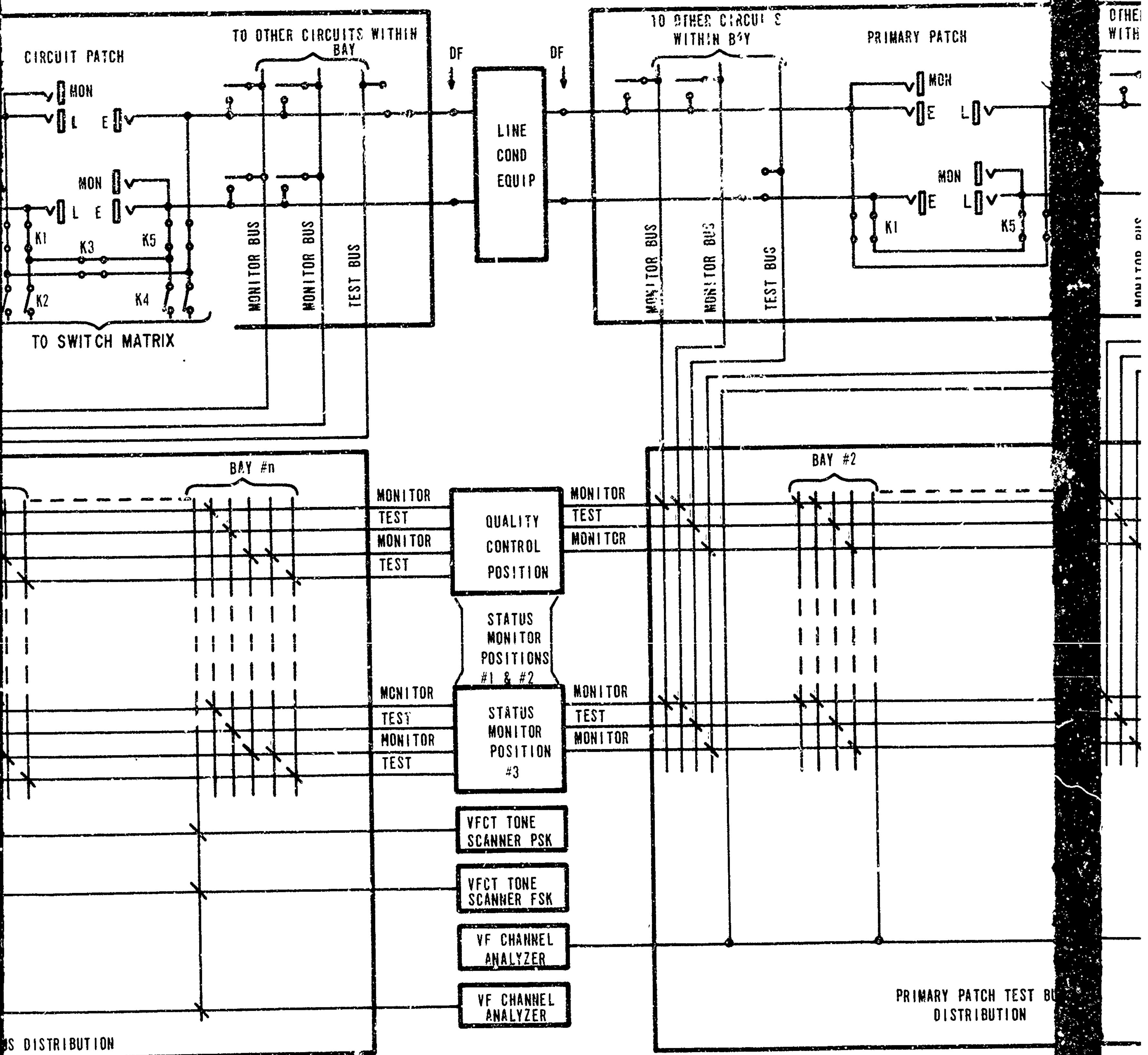
The overall test bus configuration required for ATEC is shown in Figure 13. Test buses are provided only to the circuit, primary and digital (DC) patch facilities and not to the group patch facility. The wideband group signals are at relatively low levels, so that any attempt at remote monitoring and testing would require cabling of such lengths that would introduce excessive noise pickup and insertion loss into the signal itself. Therefore, group patch facility test buses are not included in the overall test bus configuration for ATEC. Monitor access will be required and provided at the group patch panel, however, to enable monitoring and testing to be performed by maintenance personnel.

As depicted in Figure 13, the monitor and test buses from each of the circuit, primary and DC patch bays will be connected through separate matrices to the quality control and status monitor console positions, and also to separate channel monitoring equipment. Selection of a particular monitor or test bus, for connection to a particular jack appearance and further connections to the console, will be made through an instruction generated by the processor upon command from the console position. The operator will then be able to connect the appropriate operational test equipment for whatever monitoring or testing is desired. The controller will keep track of which test bus is in use, so that if another console requests access, a test bus busy response will be provided to the console requesting access. The processor will also control the operation of the separate channel monitoring equipment in a similar manner.

The buses are configured for separate functions so as to minimize the probability of a console's getting a busy indication. Each circuit patch bay has two separate monitor buses for line side terminations, and two more for the equipment side terminations. In addition, a test bus is provided on the line side for breaking into the circuit in either direction for insertion of a test signal or other transmit device, such as a VF channel multiparameter test set transmitter. A similar test bus is also provided on the equipment side for break-in and insertion of only the receive side path. Termination of the broken path is provided upon activation of a test bus. A separate 1000 Hz bus is also provided on the line side for break-in and insertion of a standard test tone in either direction. One of the monitor buses on the line side is reserved for use by the separate channel monitoring equipment, to allow for automated testing under control of the processor and to prevent interaction between consoles and automated test functions.

Monitor and test buses similar to those described above are also provided in each primary patch bay, except that the two monitor buses on the line side connect to only the receive path and the two monitor buses on the equipment side connect to only the send path. This provides for source signal monitoring,


GROUP PATCH
DF
REC
SEND
MON
L E
K1
K5
K3
TO SWITCH MATRIX
VF CHAN MUX
TO OTHER CIRCUITS WITHIN BAY
DETAIL A
MONITOR BUS
TEST BUS
1000 Hz BUS
1000 Hz TEST TONE GENERATOR
CIRCUIT PATCH
K2
TO SWITCH MA
TEST BUS
TERM
DETAIL A
BAY #2
PROCESSOR INPUT/OUTPUT INTERFACE UNIT
CONTROLLER
LEGEND
DF DISTRIBUTION FRAME
NC CONTACT
NO CONTACT
SWITCHING POINT
CIRCUIT PATCH TEST BUS DISTRIBUTION



CIRCUIT PATCH
TO OTHER CIRCUITS WITHIN BAY
DF
DF
MON
L
E
K1
K2
K3
K4
K5
TO SWITCH MATRIX
MONITOR BUS
MONITOR BUS
TEST BUS
LINE COND EQUIP
TO OTHER CIRCUITS WITHIN BAY
PRIMARY PATCH
MONITOR BUS
MONITOR BUS
TEST BUS
BAY #n
BAY #2
MONITOR
TEST
MONITOR
TEST
QUALITY CONTROL POSITION
STATUS MONITOR POSITIONS #1 & #2
STATUS MONITOR POSITION #3
VFCT TONE SCANNER PSK
VFCT TONE SCANNER FSK
VF CHANNEL ANALYZER
VF CHANNEL ANALYZER
PRIMARY PATCH TEST BU DISTRIBUTION
S DISTRIBUTION

B

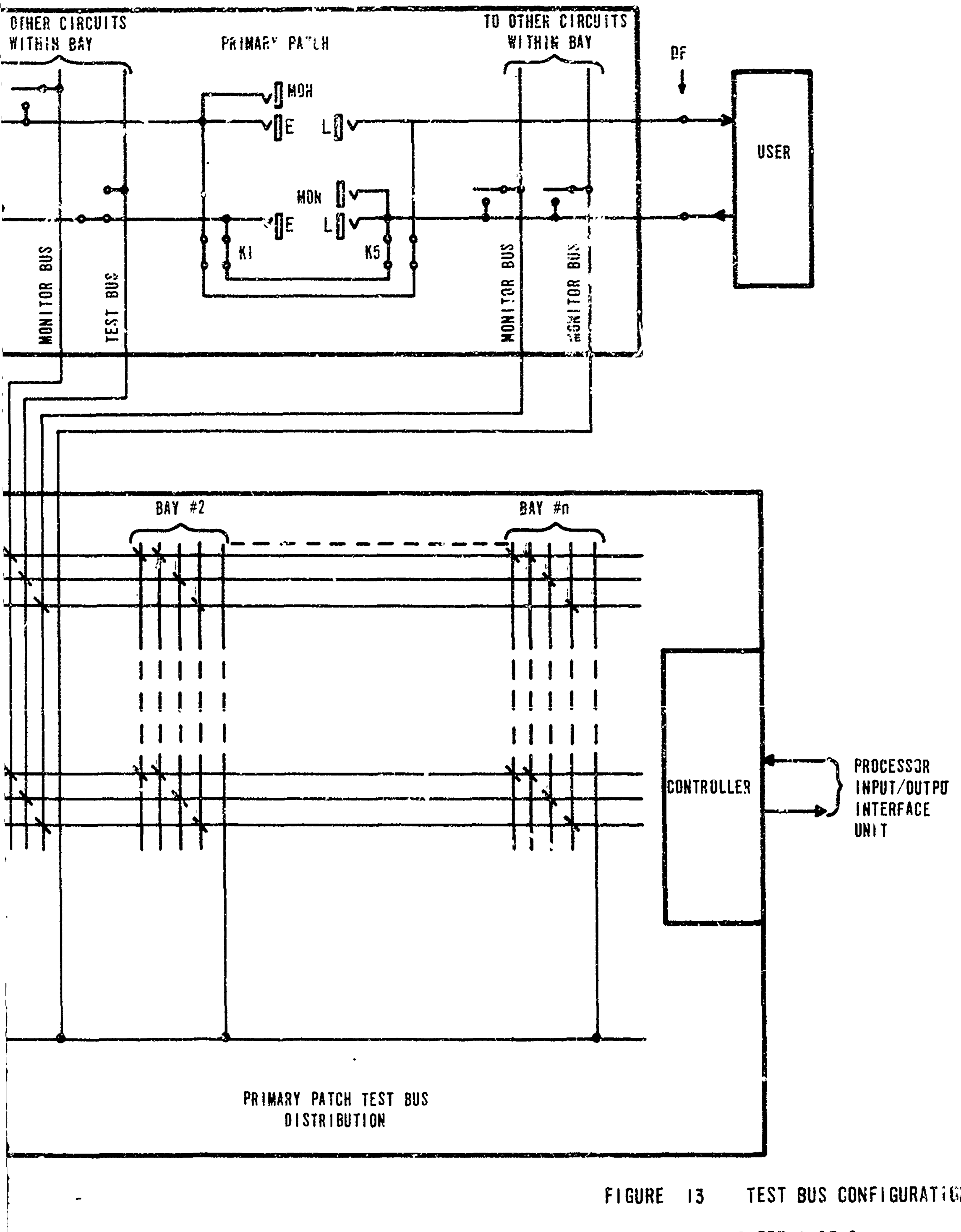
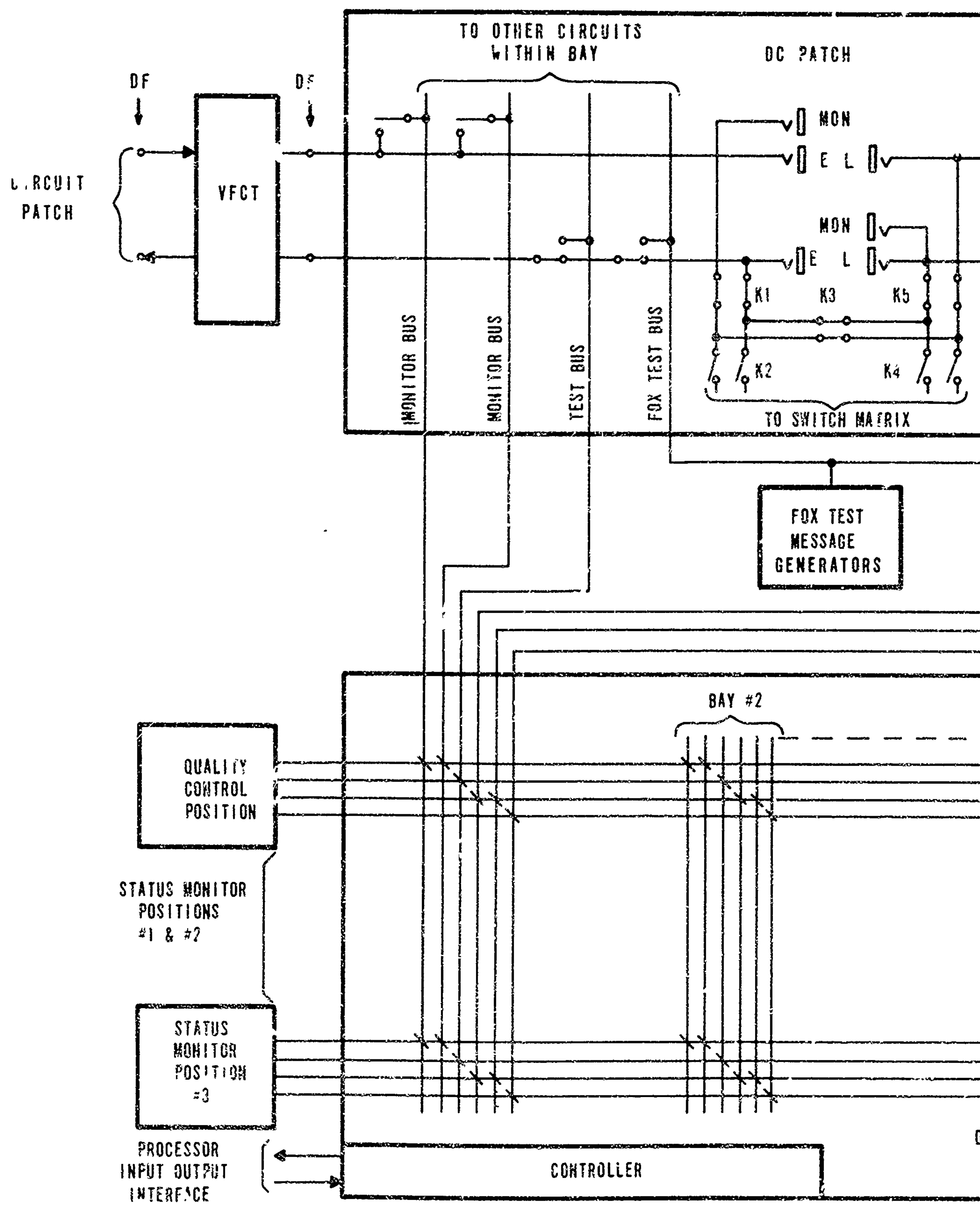


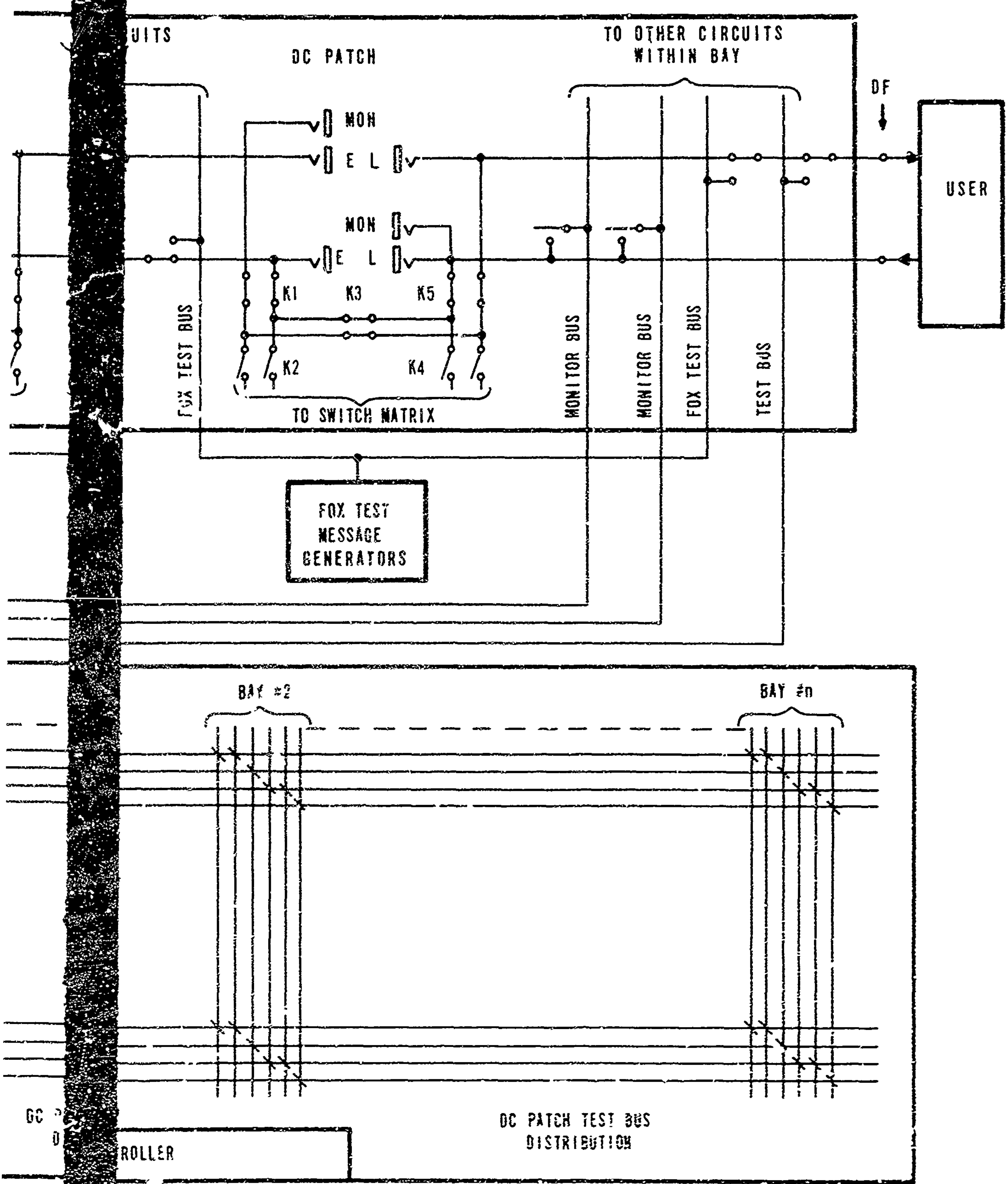
FIGURE 13 TEST BUS CONFIGURATION

SHEET 1 OF 2

C



TO OTHER CIRCUITS WITHIN BAY
DC PATCH
DF
DF
CIRCUIT PATCH
VFCT
MON
E L
MON
E L
K1
K3
K5
K2
K4
MONITOR BUS
MONITOR BUS
TEST BUS
FOX TEST BUS
TO SWITCH MATRIX
FOX TEST MESSAGE GENERATORS
BAY #2
QUALITY CONTROL POSITION
STATUS MONITOR POSITIONS #1 & #2
STATUS MONITOR POSITION #3
PROCESSOR INPUT OUTPUT INTERFACE UNIT
CONTROLLER



B

FIGURE 13 TEST BUS CONFIGURATION

SHEET 2 OF 2

127 125

which is all that is actually required at these points of the circuit. The reason that full capability was provided in the circuit patch, for the test buses to access both paths, is that more testing and monitoring will be performed at this point in the circuit by both manual and automated test equipment. The other exceptions, from the circuit patch, are that there is no 1000 Hz bus in the primary patch and there is only one test bus; it is located on the equipment side for breaking into the receive patch and for insertion of a test signal. Termination of the broken path into its characteristic impedance is provided upon actuation of the test bus. The reason there is no test bus access on the transmit line or equipment side is that all test access toward the user will be done at the equal-level circuit patch. The test bus in the primary patch is to be used primarily for tests of the line conditioning equipment.

Each DC patch bay, as shown in Figure 13, will be provided with monitor and test buses to perform all testing functions normally available at a manual DC patch facility. Two monitor buses are provided on the equipment side transmit path, and two more monitor buses are provided on the line side receive path. This again, as in the primary patch, provides for source signal monitoring and thereby allows for monitoring of signals on a back-to-back patch, in addition to normal monitoring functions. All monitoring will be in parallel with high resistance input devices of greater than 6000 ohms with a design objective of greater than 50,000 ohms, in accordance with MIL-STD-188B. This will be done because the digital signals themselves will be low level, 6 volt polar, in accordance with MIL-STD-188B, paragraph 3.2.4.1.1. The digital signal circuits will be single-wire with controlled earth return, so that the monitor function will only need to access the tip circuit for teletypewriter channel monitoring. However, the ring circuit will also be accessed, since it will be used for clock signal on data circuits and provisions will be made to selectively monitor the tip and ring at the console positions. This also means that the relay access and switching matrix circuitry will be essentially the same for all patch facilities, thus making for a standardized arrangement and interchangeable configurations.

The test buses in the DC patch bays provide for break-in and insertion of a test signal, such as a bit error rate test transmitter output, or a keyboard of a teletypewriter set. Two test buses are available, one for break-in on the equipment side receive path and one for break-in on the line side transmit path. In addition, two FOX test buses will be provided to allow for insertion of a teletypewriter test signal from a common station test message generator. One FOX test will be provided on the equipment side receive path, and one on the line side transmit path. There will actually be two rates of FOX test, one at 45 baud and one at 75 baud. Determination of which rate is to be applied to a particular circuit will be done on an individual basis, after coordination with distant end ATEC, TCF or PTF, and will be accomplished by a strapping option on the particular relay board in the DC patch bay.

3.3 Programming and Processing

3.3.1 Data Processing Hardware

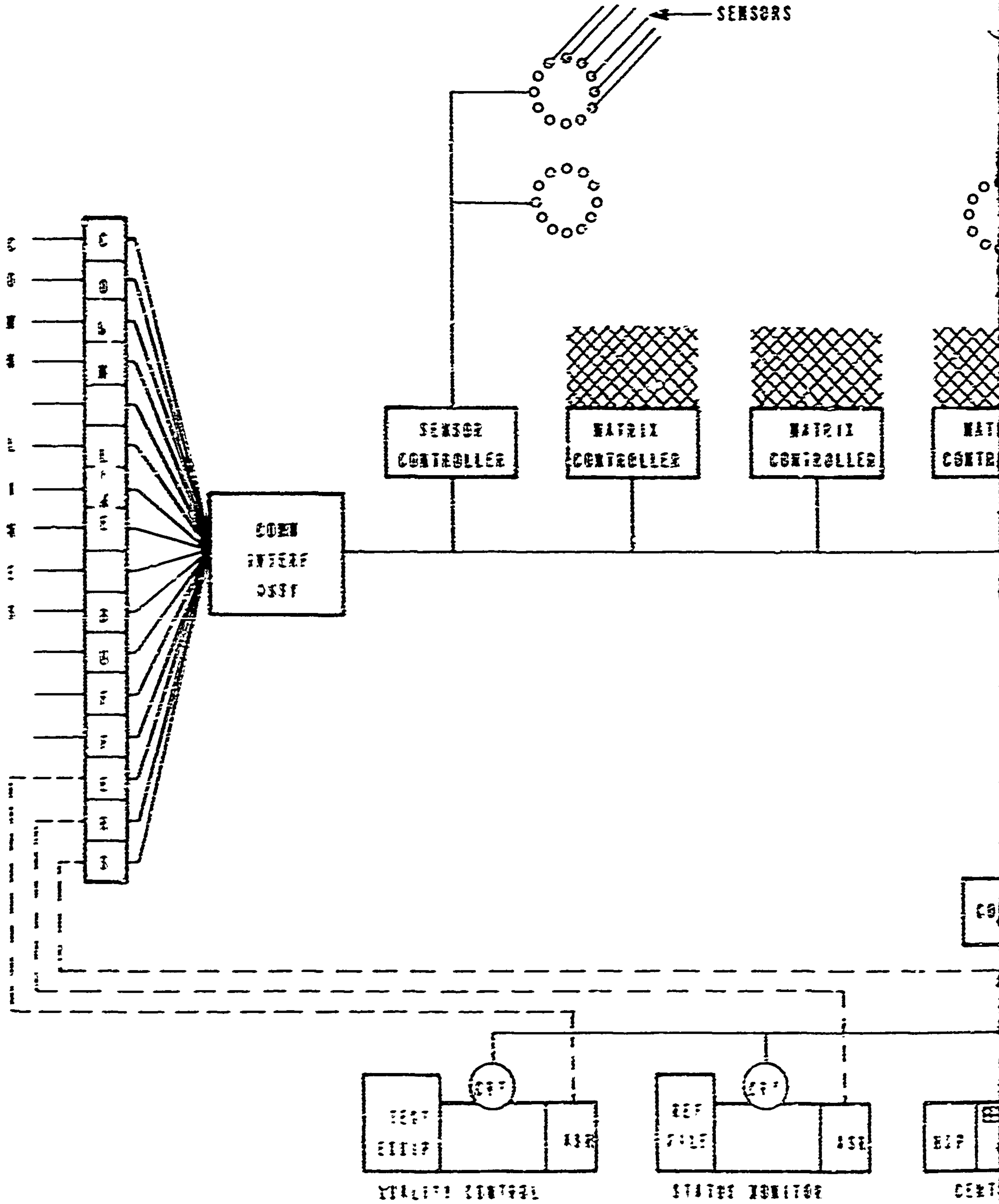
The processing subsystem will consist of a programmable computer-type processor, main memory (core) modules, internal clock module, direct-memory-access (DMA) module, memory protect and parity check features, peripheral magnetic tape and random-access mass-storage equipments. The processing subsystem is interfaced with sensor-associated, switching-associated and communication-line-associated equipments as well as Technical Control operating position consoles. A configuration of a processing subsystem suitable for this Technical Control application, showing the kinds of hardware with which it will interface, is depicted in Figure 14.

3.3.1.1 Processor Input/Output Interface Unit

Inputs to and outputs from the digital processor originate from and terminate at various external devices. These external devices include: equipment sensor scanners; channel (circuit) scanners, both analog and digital; VFCT tone scanners and distortion analyzers, switching matrices controllers, and communications lines "carrying" telemetry and reporting data. In order to transfer information between these external devices and the processor, which is equipped with an input/output bus arrangement, an interface unit is required to provide proper routing and buffering of the information. The information being transferred includes sensed status data, external device control data, and external control device acknowledgments. All external devices are to be under control of the processor. Therefore, all information that transfers through the interface unit requires that the interface unit decode the instructions received from the processor and connect the appropriate external device to the processor. All information exchange between the external devices and the interface unit is to be in bit-serial form. In order to minimize transfer time, all information exchange between the interface unit and the processor is to be in word-parallel form. Hence, the interface unit will be required to perform serial/parallel and parallel/serial conversions. Four types of information transfer are required of the interface unit, namely:

a. High speed (nominal 250 kHz) information input from external devices, with clock being provided by the interface unit. The external devices will provide an indication of the availability of information.

b. High speed (nominal 250 kHz) information output to the external devices, with clock being provided by the interface unit. The interface unit is to provide an indication of the availability of information.


SENSORS
SENSOR CONTROLLER
MATRIX CONTROLLER
MATRIX CONTROLLER

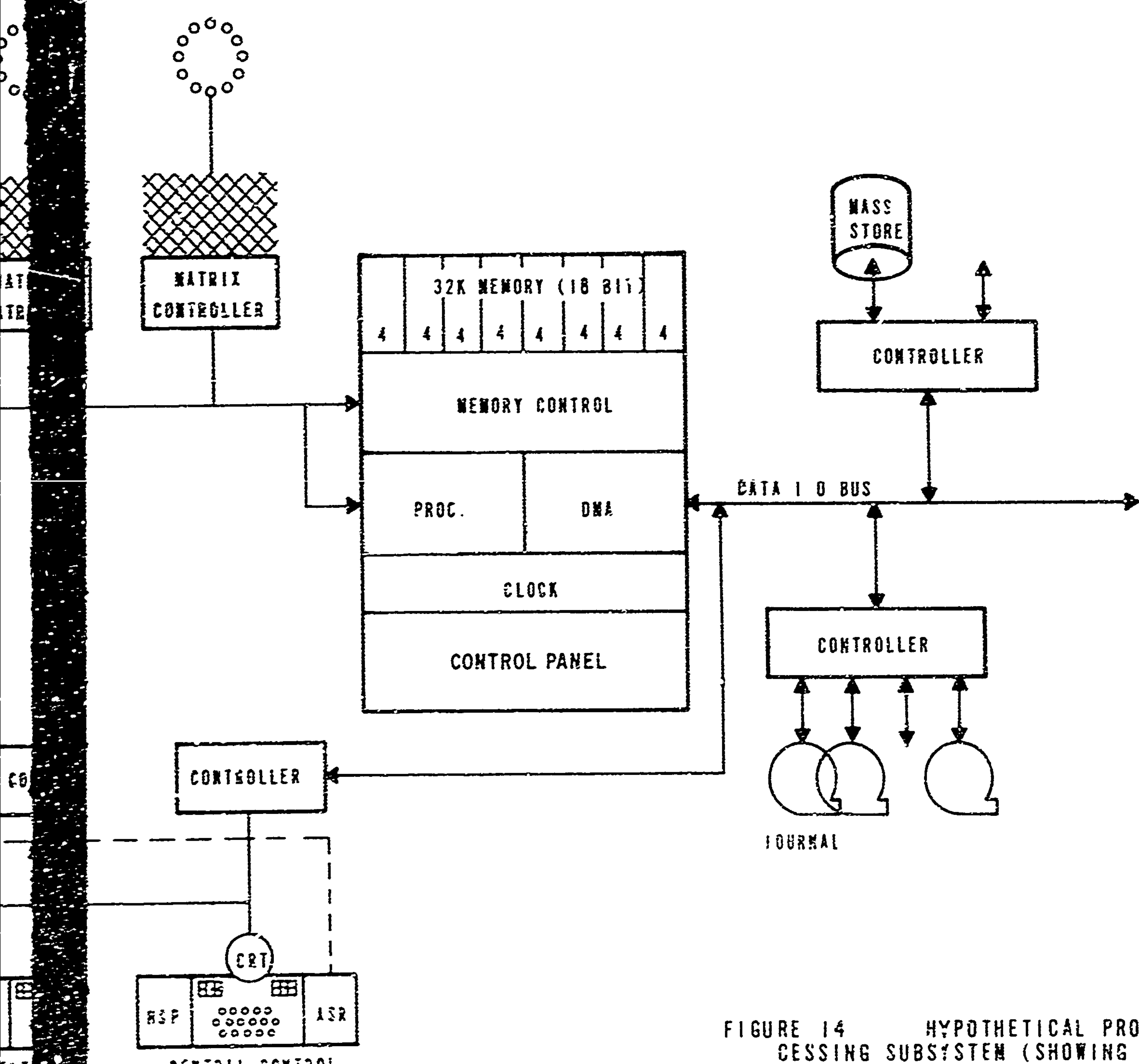


FIGURE 14 HYPOTHETICAL PROCESSING SUBSYSTEM (SHOWING TYPES OF INTERFACES)

c. External device control data (step pulses, to advance scanners to the next position, and to reset scanners to the "home" position). The interface unit is required to: decode a single processor originated instruction and generate a reset pulse for all external devices; decode numerous processor originated instructions; and generate a separate advance pulse or a separate reset pulse for each of the external devices.

d. Full-duplex teleprinter data (ASCII at 75 and 110 baud) for local and remote telemetry and scanning devices/circuits. The interface unit is to add/delete start-stop pulses as required.

The quantity of each of the four types of information transfer is dependent upon the number of external devices implemented at a given ATEC facility. Modularity of design is required to permit expanding the interface unit to accommodate the expected diversity in sizes of ATECF. All external devices interfaces are to be standardized to conform with MIL-STD-188B, low level. The interface unit is to be compatible with the input/output characteristics exhibited by the processor employed at the ATECF.

3.3.1.2 Processor Characteristics

Certain characteristics were identified as requirements for the processor to be used in the processing subsystem of the ATEC facility. These characteristics are:

Characteristic	Reqmt.	Comment
Memory Cycle Time	$2 \mu s$	A two microsecond or better cycle is common on today's small processors. Memory cycle time is a key characteristic of performance. Cycle time, when combined with address field and number of operation codes, is indicative of execution timing.
Memory Word Length	16 bits	A sixteen bit word length results in sufficient size for operation codes and address to provide a reasonably extensive complement of instructions and an ability to address directly a large segment of memory. A large complement of instructions will conserve memory and result in faster program execution. A large address field means more memory is directly addressed with a resultant lowering of execution time.

Processor Characteristics (Continued)

Characteristic	Reqmt.	Comment
Memory Size	32K	The maximum memory size puts an upper limit on expandability. The minimum memory size, while not as critical, points to flexibility and cost-effectiveness for small installations. A small increment of memory size permits expansion in small cost units. Therefore, the most desirable combination of size characteristics is a small minimum memory, a small increment, and a large maximum.
Parity	Yes	Memory parity checking permits immediate detection of transient or permanent memory problems before these problems have an opportunity to propagate themselves throughout the system.
Instruction Length	= Memory Word Length	A memory word length of sixteen bits has been specified previously. The instruction word length should be equal to the memory word length for compatibility between data and instruction words. The advantage of a relatively large word length in permitting a range of operation codes and extensive directly addressable memory is discussed under Memory Word Lengths.
General or Accumulator Registers	[illegible]	A minimum of two accumulator registers is required to permit a variety of shift operations as well as double length arithmetic operations. A greater number of accumulators (or general registers that may perform accumulator functions) permits greater flexibility to the programmer to increase execution efficiency through fast register-to-register operations rather than relatively slower memory transfers.

Processor Characteristics (Continued)

Characteristic	Reqmt.	Comment
Index Registers	1	An index register is a valuable address modification and counting tool which results in execution timing efficiency as well as making a contribution to ease of programming. Most desirable is a large number of hardware index registers. A small number of registers, index registers in memory, or substitute indexing techniques result in difficulty of programming by forcing the programmer to do more housekeeping or require greater amounts of time due to loading registers or additional memory accesses.
Directly Addressable Memory	1024 words	This is a direct function of the address length within the instruction word. Most desirable is direct addressability. Where there is direct addressability to small areas of memory (i.e., less than 1024 words), movement of data into the directly addressable area, batching of data, or indirectly addressing a large area of data are techniques for offsetting the effects of the restricted area addressability. Any of these techniques will increase execution time due to indirect operations requiring more memory accesses or due to more movement of data. Program development costs will rise when the direct-addressability area is decreased due to an increase in the complexity of the programming or an increase in volume of instructions that must be written and tested.
Direct Memory Access (DMA)	Yes	The volume of program instructions and data that must be transferred between the random access device (disc, drum, etc.) and core memory precludes putting the random access device on an input/output bus which requires processor intervention and instruction time execution to transfer individual words.

Processor Characteristics (Continued)

Characteristic	Reqmt.	Comment
DMA Transfer Rate	1 memory cycle/word	Movement of one word of data into or out of core should require no more than one memory cycle. Relaxation of this requirement will result in a slower channel speed (device to core) as well as fewer memory cycles being available for processing and input/output bus service.
Interrupt Service Time	20 microseconds	A fast response time to interrupts permits the system designer to specify an interrupt-driven system where indicated. This results in more flexibility of program design, thus making program development easier and enhancing capability for expansion.
Real-Time Clock	Yes	A requirement dictated by the real-time nature of the processing.
External Interrupt Levels	2	At least one external interrupt level is required to service the direct memory access channel, and one to service the input/output bus. Lack of external interrupts at the minimum requirement will adversely affect programming development costs as well as execution timing.
Number of External Interrupts	16	Ability to service a number of devices effectively on the input/output bus is contingent upon the number of interrupts that may be serviced. The requirement covers anticipated device terminations and provi[illegible] for expansion.
Instruction Times	Store Add 2 cycle times	Two instruction times, which are indicative of the speed of execution of the entire instruction set, are times to store a word or add two words. This requirement, coupled with the requirement for a 2 microsecond memory cycle time, would result in an add time or store time no greater

Processor Characteristics (Concluded)

Characteristic	Reqmt.	Comment
Instruction Times (concluded)		than 4 microseconds. While this time is not critical to the internal processing of the operational program, an add or store time greater than 4 microseconds should serve as a warning.
Fixed Point Multiply/Divide	None	The main requirements of the ATEC operational programs will be for logical and data movement operations. Lack of fixed point multiply/divide or floating point arithmetic will not materially degrade performance.
Floating Point Arithmetic	None	

3.3.2 Program Structure

This Technical Control-related application requires use of on-line and real-time techniques for data processing. Programming is expected to be performed using relocatable assembler language, in consideration of a large volume of tabular information and the handling of bit-fields in its operation. A real-time modular Executive Routine and Application Program Modules are to be developed for the Processing Subsystem. The recommended modular structure of the operational programs is depicted in Figure 15.

The Executive Routine is that program section which controls the sequence of calls for service of the various operational application program modules. The sequence of calls will be made in cyclic order - not necessarily sequential among the various functions. Because of the diversity of interfaces, the executive routine must have modularity. The executive will call each function module as a closed subroutine, at completion executive will step to the next eligible function. The Executive Routine will consist of a scheduler/dispatcher module, supported by modules for an internal clock, for start-up and for recovery, and will include other separate "handler" modules for matrix controls, communication line controls, sensor-scanner controls, tape devices controls, disc controls, keyboard controls, teleprinter controls, and display controls.

Application program modules are required to be developed for each of the major processing functions: Sensor Processing, Operator Inputs, Matrix Control, Acknowledgments, Queries, Journaling, Message Generation, Status Update, Display/printouts and Other Outputs apply.

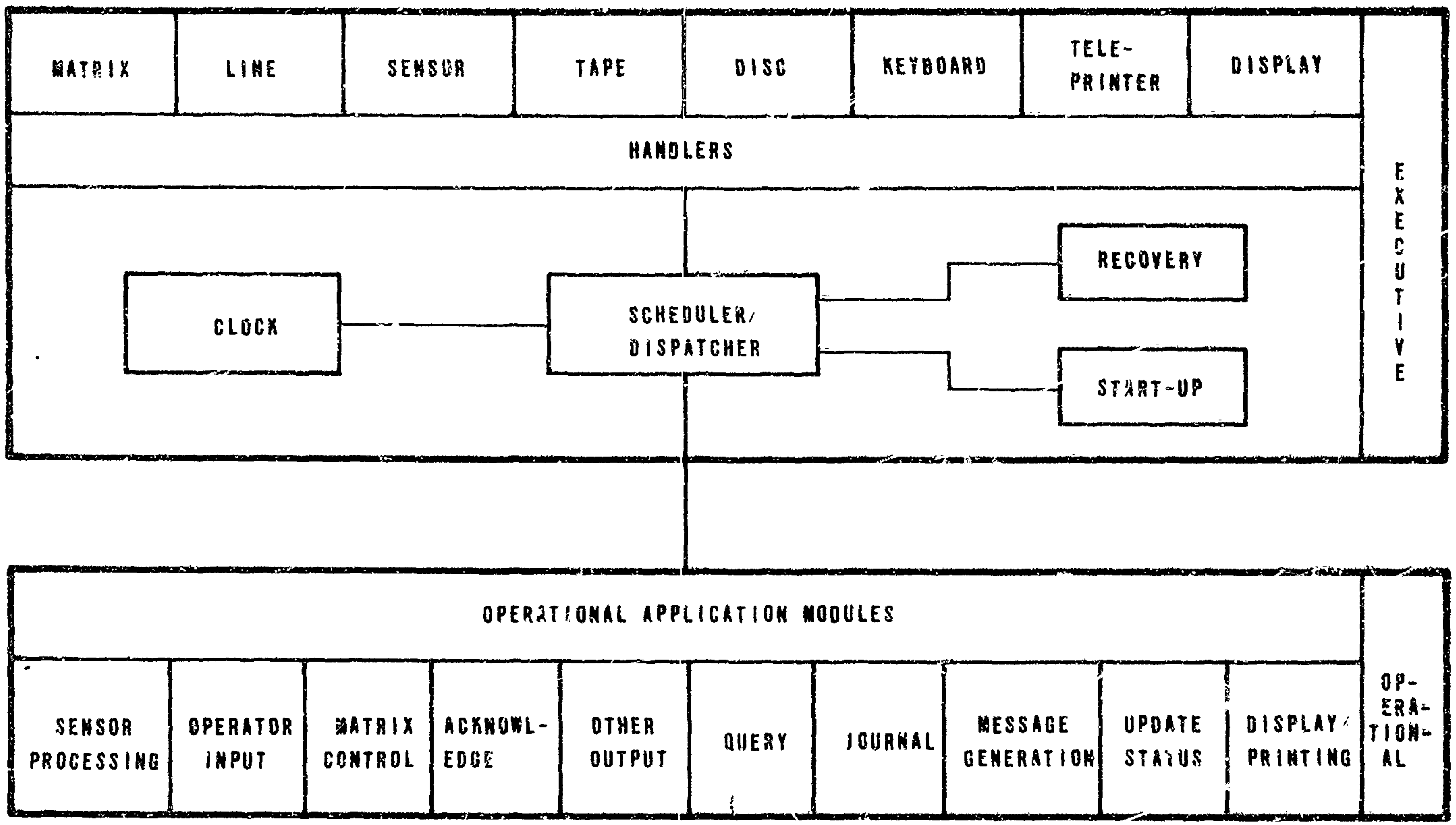


FIGURE 15
OPERATIONAL PROGRAM STRUCTURE

3.3.3 Data-Base Files

The data-base file requirements for operation in the processing subsystem must contain information applicable to each ATEC facility from the DCS Directory or Reporting Guide, the DCS Frequency Directory and circuit activation (Communications Service Orders) and related documents. The data-base must also include identifications of sensors; sensed-parameters; sensed-parameters for variable states, if applicable; related thresholds and condition ranges; conversion lists; and a means for association of each of the sensors with communication entities and/or equipment entities. Further, the data-base must include an equivalent of an equipment inventory, and a means for association of equipments with the communication entities which each supports; spare operational equipments as well as equipments undergoing repair are to be included in the data-base to provide a means for determining capability. The means for associating the various entities must provide a continuity to the entire data-base to form a cohesive file; each item of the data-base may be required to be associated with more than one other item. The data-base file requirements can be visualized according to primary major processing functions as represented by the application program modules of the Operational Program Structure depicted in Figure 15.

For sensor-processing functions, the data-base must include the identity of each of the sensors in the sequence in which they are to be scanned under control of the processor/programs. Group-lists of identical sensors, which sample identical parameters and have been assigned identical parameter values for the various (Red, Amber and Green) conditions, must be formed for common criteria use. The sensor identifications must include each "state" (speech, no speech, etc.) in which the communications can operate during sensing. The signal parameter name or other identification should be meaningful to the Technical Control operators when automatically presented in displays and printouts. Measurable parameter thresholds and condition ranges must be pre-established in the data-base. Each threshold must be a fixed value level; conditions (Red, Amber and Green) can extend over a range of value levels. The value levels and condition ranges must be pre-established within the maximum range of the sensor outputs converted into a digital form representing the signal levels.

For trend analysis functions associated with sensor-processing, the Amber ranges will be expanded to include intra-Amber-range thresholds for inclusion in the data-base. Trend analysis will be performed when two intra-Amber-range threshold crossings were experienced upon entering the Amber range. The results of trend analysis is an automatic prediction when (time) a Red threshold will be experienced, assuming the same degradation rate as experienced in previous threshold crossings.

For Status-Update functions, an equivalent of an inventory (a listing only) of the communication and equipment entities is required in the data-base. "Status" will be posted with the effected entities by the status-update application program module as the information is gathered through automatic communication performance monitoring analysis and operator entries of information. Each entity must be considered a separate item for posting purposes, but the files must be organized in a hierarchy with higher-level entities. Files must be organized by station, by location, by communication and equipment entities. This information must be organized in data-base files for residence on the random-access mass-storage device in a manner that allows and permits sufficient additional storage space to be utilized to accommodate an accumulation (preferably for a full audit day) of postings of status with the affected communication and equipment entities. The same status information, in most instances, will be posted to more than one entity, and these postings will have an effect on the status of higher-level entities. The Send and Receive directions of channels and circuits are considered the elementary items of the communication entity files. Communication entities, as established for the DCS, chiefly in the DCS Directory, will be utilized. Non-DCS communication entities should conform to the DCS methods for identification construction. Circuit entities will consist of the Command Communications Service Designator (CCSD), and the commercial number if a local segment of the circuit is leased. Channels, by directions, will be identified by complete channel numbers (up to 6 numerics), CCSD of the circuit it supports and its assigned restoration priority. Equipments should be identified by military (AN) nomenclature and should include a descriptive name for the class of equipments (such as Modem, Multiplexer, etc.). Organization of equipment entities in the files must include a means for associating each equipment entity with the communications it supports on a permanent basis, and allowing for the association of communication entities it may support on a temporary basis.

For certain queries from operators and for certain displays and printouts, the Processing Subsystem must store what might be called a Static Data-Base as a differentiation from the previously referenced Dynamic Data-Base files. The Static Data-Base is chiefly a background information file to be accessed by operators to obtain proper identifications, configurations, operating Technical Control parameters and other information about the communications and/or equipments. It is a complete record containing all information that may be needed by the Technical Control operators about the communications and equipments of the ATEC facility. This type of record for DCS communications must be kept up-to-date by Technical Control operators for submission to HQ DCA for update of their DCS Directory.

The Static Data-Base must contain the DCS Directory listings for Links, Trunks and for Circuits for which the future ATEC facility will be

responsible. These listings are required to reside on the random-access mass-storage device in files in somewhat the same format as currently contained in the DCS Directory and maintained in DCA computers. Similar listings for non-DCS communications, organized in a like manner, will be required. These listings will represent the identifications, make-up, configurations, and operating Technical Control parameters of the communications which terminate and/or pass through the station or sector of responsibility of the ATEC facility. The Link/Trunk listings contain identifications and channel make-up (by supergroups and groups for links) to include the user allocation (assignment to circuits) of each channel. The circuit listings contain identifications, operating Technical Control parameters, and the complete routing, by segments between locations serving as connecting points, segment-by-segment, from user-end to user-end, by direction. The circuit listings may be grouped in the data-base files by "local-user circuits" and "through circuits," in order of assigned restoration priority. Within these groups or in a separate grouping, the preplanned reroutes for the high-restoration-priority circuits must be included, so that the processor programs can 'suggest' the preplanned reroute for the appropriate circuit when the primary route is inoperative, and answer queries about established preplanned reroutes. Certain other information about frequencies assigned and permitted on different communication paths, circuit characteristics, equipment configurations for circuits, and station connectivity must be available for display presentations or printouts upon request of the Technical Control operators of the ATEC facility.

3.3.5 Processing

For automating the communications performance monitoring function, the Processing Subsystem will monitor the send and receive side (as noted in the data-base) of all circuits at the points where they egress from the local station or geographical sector of immediate responsibility. The needed measurement parameter values will be derived as a result of fast sensor-scanning at the egress points. The scanning process and the transfer of level indications in digital form to the processor main memory will be controlled by the processor programs. These parameter levels will be compared by the processor programs with prestored level ranges and thresholds for Red, Amber, and Green conditions to determine circuit status. When a circuit condition is determined to be Red or Amber, the processor programs are to automatically isolate the location of suspected faults as being external or internal to the station or geographical sector of immediate responsibility. This internal-external isolation is to be accomplished by automatic switching actions initiated by the processor programs to switch-in additional sensors and test equipments to monitor the affected communication performance at the internal points of ingress into the station or sector of immediate responsibility of circuit status. During this automatic

monitoring, parameter level indications will be transferred to the processors' main memory in the same manner as for those points monitored at the points of egress, and will be compared with prestored levels in the same way. As a result of this so-called monitoring, when the processor programs determine that the faults are located internal to the station or geographical sector, then further monitoring, at least at one additional point between the point of ingress and point of egress, will be automatically made by the processor programs to further isolate the faults to a specific or a series of equipments, or their interconnections. Prior to the internal-external isolation process, the processor programs will associate the known Red or Amber indications of the various circuits so monitored to determine whether or not they are partially or fully directed to common equipments of the station. Then groups of circuits with a common status can be isolated. The circuit monitoring described above will be performed in addition to monitoring of fixed sensors located in or on equipment entities. Other associations between affected circuits and supporting equipments will be made by the processor programs. From the parameter level indications, trend analysis and predictions will be made by the processor programs when two and more parameter level indications are of different values in the Amber range for either circuits or equipments. The results of this monitoring, fault isolation, status analysis and trend analysis are to be presented as an alarm and as a display to the appropriate Technical Control operating position, and be included in Activities and Master Station logs. The results are also to be recorded as dynamic status information in the random-access mass-storage for an accumulation of the total station status, and as entries on magnetic tape for subsequent retrieval purposes.

For Red and Amber conditions of a communications entity (station, link, supergroup, group, circuit, channel or user service), the processor programs will determine whether the condition is reportable or non-reportable. Reportable conditions will be appropriately tagged in the data-base. Reportable conditions will be timed for operator notification, for his supplementary inputs or changes, approval/release until the required time-to-report. Then the required report will be transmitted automatically when a communication circuit to the appropriate OA/M agency or DOCC element is available to the processing subsystem for this purpose, or the text of the report message will be punched out in paper-tape form at the operator's option as appropriate to the ATEC facility.

3.3.4.1 Internal Failures or Degradations

The initial CRT display with audible alarm of Red or Amber conditions as a result of both communications and equipment performance monitoring, will contain sufficient information from which the Technical Controller can verbally through intercom or otherwise consult with maintenance personnel regarding in-station failures or substandard operation of equipment. For maintenance

notification, the processor programs will generate the equivalent of a work order containing chiefly the same information as the Technical Control operator's display and will include a sequential number and produce a printout via a teletypewriter at the maintenance terminal. The consultation between the Technical Control operator and the maintenance person should provide a basis for decisions and appropriate action, if any, on the part of the Technical Controller. For Red conditions, the decisions for restoral action should be made, especially for high-restoration priority circuits based on the maintenance person's estimate of the work and period of time required to correct the suspected faults.

During or immediately after the maintenance period, information relative to significant maintenance status and reason-for-outage must be supplied to the processing subsystem for inclusion in any reports that may become due as a result of a Red or Amber condition, for completion of the maintenance work order records, and for posting in the dynamic data-base as status information for requested displays.

3.3.4.2 External Failures or Degradations

When a Red or Amber condition for all circuits supported by a specific transmission entity (link, supergroup or group and tandem) from a specific adjacent Technical Control facility is automatically isolated as being located external to the local station, an Operational Coordination Message (OCM) can be automatically generated from certain preselected canned information, significant monitored performance information and data-base identifications for transmission to the adjacent Technical Control facility. This OCM will be transmitted automatically when automatic orderwire or other circuit to the adjacent Technical Control facility is available to the processing subsystem. Otherwise, Technical Control operators must coordinate these types of conditions manually, using available orderwire or other interconnecting means.

When a Red or Amber condition for an individual circuit is automatically isolated as being located external to the local station, the processor programs will determine whether the circuit is a through circuit, or a local subscriber circuit for which the ATEC facility has the reporting responsibility. These local subscriber circuits will be appropriately tagged in the data-base. For a through-circuit, an OCM can be automatically generated in the manner described above for transmission to the adjacent Technical Control facility. Local subscriber circuit outages (Red condition) will cause the processor program to include any preplanned restoral information contained in the data-base for the circuit user in the initial display, with audible alarm, at the operating position CRT face. These circuit outages will generally be reportable in one or more formal reports. The responsibility to include the type of reports (near-real-time or As-Occurs), which require reports in 15 minutes will be included in the displays as a form reminder to the Technical Control operator to supply supplemental information, such as reason-for-outage, for inclusion in formal reports.

3.3.4.3 Operator Reactions

As a reaction to automatic communication and equipment performance monitoring and display of significant information with alarms, the operators are expected to either take immediate restoral action or request additional related information for display or printout from the processing subsystem. These actions and requests for information will be made in the form of commands to the processor/programs. The commands will be normally generated by use of programmed-function-keys to identify the particular command to the processor/programs, and the typewriter-type keyboard associated with the CRT device for entry of parameters of the command. Depression of a programmed-function-key for this purpose will cause the processor/program to generate the format of the command on the CRT face with an indication where (and which) parameters are required to be entered via the keyboard. The operator can cancel this display by use of a cancel key. When the required parameters are "typed" on the CRT face by use of the keyboard, the operator will also depress the go or input key to enter the information. If the operator depresses the go key prior to providing the minimum required parameters, or if he makes errors, the processor/program will denote the command input invalid. The processor/programs will respond [illegible] only as a result of input of totally valid commands.

Restoral actions by operators will generally be performed by semi-automatic switching through the processor/programs. Semiautomatic switching may be performed by the Technical Control operators as a corrective action function for reconnection of user terminal equipment or subscriber lines, from a primary circuit route, to an alternative preplanned circuit route, or for reconfiguring an unplanned circuit route when both the primary and alternative preplanned routes are not operational for high-restoration-priority circuits. Semiautomatic switching may also be performed by operating personnel for testing purposes, i.e., connecting test equipments to circuits or to equipments supporting communications, or for substituting equipments when this capability is provided. The switching commands are entered into the processor for the programs in the same manner as previously described. The processor/programs accept these valid commands, then generate and issue device-control-word instructions to the hardware controller of the appropriate switching matrix to make and break specific crosspoints of the switching matrix. The controller either confirms making and breaking of the appropriate crosspoints or indicates a blocking condition of the matrix to the processor/programs. This confirmation or blocking is relayed to the operating position with instructions for manual patching to accomplish restoral action if the condition was blocking. If the controller does not perform the manual patching action in a reasonable length of time, it will remind the operator of this expected action a second time. This expectation of operator manual action can be cancelled by the operator by commanding the processor/program

to cancel it. When manual patches are made through the use of patchboards, the processor/programs verify, through patchboard sensing, that the proper manual patches were made. If improper patches were manually made, the processor/programs will notify the operator accordingly.

Operators will request displays and printouts of information from the processing subsystem. These requests will be entered into the processor for programs in the form of commands or queries. These will be requests for the status of specific communication entities, groups of entities, or status for the entire station. They may also be for communication entity configurations or make-up. They may be queries about specific communication or equipment entities. Some of these requests or queries may constitute a volume of information for printout on the high-speed-printer. Most requests are presented on the CRT faces of the operating position consoles. All valid requests will be honored. When the amount of information to be presented on the face of the CRT display exceeds its one-time display capacity, the operator can roll the presentation to view the next block of information.

3.3.4.4 Program Characteristics

General program characteristics were categorized to determine which were needed and desirable for the processing subsystem. These program characteristics were categorized as follows:

M = Mandatory
D = Desirable

1. General

• Modular programming	M
• Standard interface between modules	M
• Relocatable assembly language	M
• Processor assembling of own coding	D
• Cyclic executive operation	M
• Conservation of volatile memory	D
• Periodic snapshot of volatile memory	M
• Recovery program	M

b. Sensor Monitoring

- Separate I/O module M
- Direct relationship between sensor identity and the location of its related data D
- Verification of getting data from all sensors M
- Minimized alarms for sensor transients M
- Detection that a sensor value has crossed its threshold M
- Independence of thresholds between sensors M
- Optional operator notification on threshold crossing D
- Optional notification depending on logical analysis between several threshold crossings D
- Destination of notification dependent upon sensor M
- Prediction of Red threshold crossing (trend analysis) D

c. Acknowledgment

- Acknowledgment where possible D
- Redundancy parity check where possible D
- First level failure redundancy D
- If no ACK 3 times, tell operator D
- NACK if known bad D
- Minimum format for acknowledgment D

d. Motor Control

- Output to motor hardware M

d. Matrix Control (concluded)

- Hard copy of every command to matrix — M
- Different format output in manual matrix control center — D
- Operator acknowledgment in manual case — M
- Reminder if no ACK in manual case — M
- Automatic module different from manual module — D
- Update status tables after ACK — M

e. Display

- Single entrance control of module — M
- Sub-modules for each device — M
- Display-request is device independent — M
- Substitute display device — D
- Expandability to new output devices — D
- Partial display of data per call — D
- Queuing of display requests — M
- Priority message display capability — M

f. Operator input

- Single entrance control module — M
- Sub-module for each device — M
- Input conversion to common internal code — M
- Acknowledgment to operator of input — D
- Conversational capability — D
- Input security verification — D

g. Query

• Queries from all devices only differentiated by originator's code	M
• Authorization to make query request	M
• Unauthorized queries recorded	D
• Query totally determined before data-base format finalized	M
• Specific search for high-volume queries	D
• Query journaling	D
• Query from any input device	M
• No free-form natural language query	M
• Bulk storage random query mechanism	M

h. Status Update

• Current status of every device	M
• Centralized updating	D
• All critical information in each entry	M
• Independence of entries	M

i. Other Output

• Central module and sub-module structure	M
• Catch-all for little used output devices	D

j. Message Generation

• Consolidated message generation module	M
• Parameter at entry selects format from table	M
• Open-ended	M
• Predominantly mass storage resident	D

k. Recovery

• Storage of all volatile data on mass storage	M
• Minimum bootstrap in memory	M
• Validity check on recovery data	M
• Recovery program leaves no traces after running	M

l. Journal

• Table of formats	M
• Entry for every significant event	M
• Numbered tape blocks	M
• Journal entry parameter is minimal	M
• Mass store accumulation if tape not available	M
• Warning to operator of tape maintenance	M

m. Executive

• Table driven	M
• Table entries specify function entrances	M
• Cyclic storage of recovery data	M
• Functions called as closed subroutines	M

3.4 CONSOLE DISPLAY AND CONTROL EQUIPMENT

The display and control analysis task report (Section XVI of Volume II) provides an in-depth examination and evaluation of console requirements for the ATEC facility. The following paragraphs provide a summary of the display and control analysis findings and also introduces requirements that have evolved through analysis of the ATEC facility.

3.4.1 Console Positions

From system analysis developed in Section III, ATEC System Concepts, the types of console positions have been defined from functional requirements as:

a. Status monitoring

b. Quality control

c. Central control.

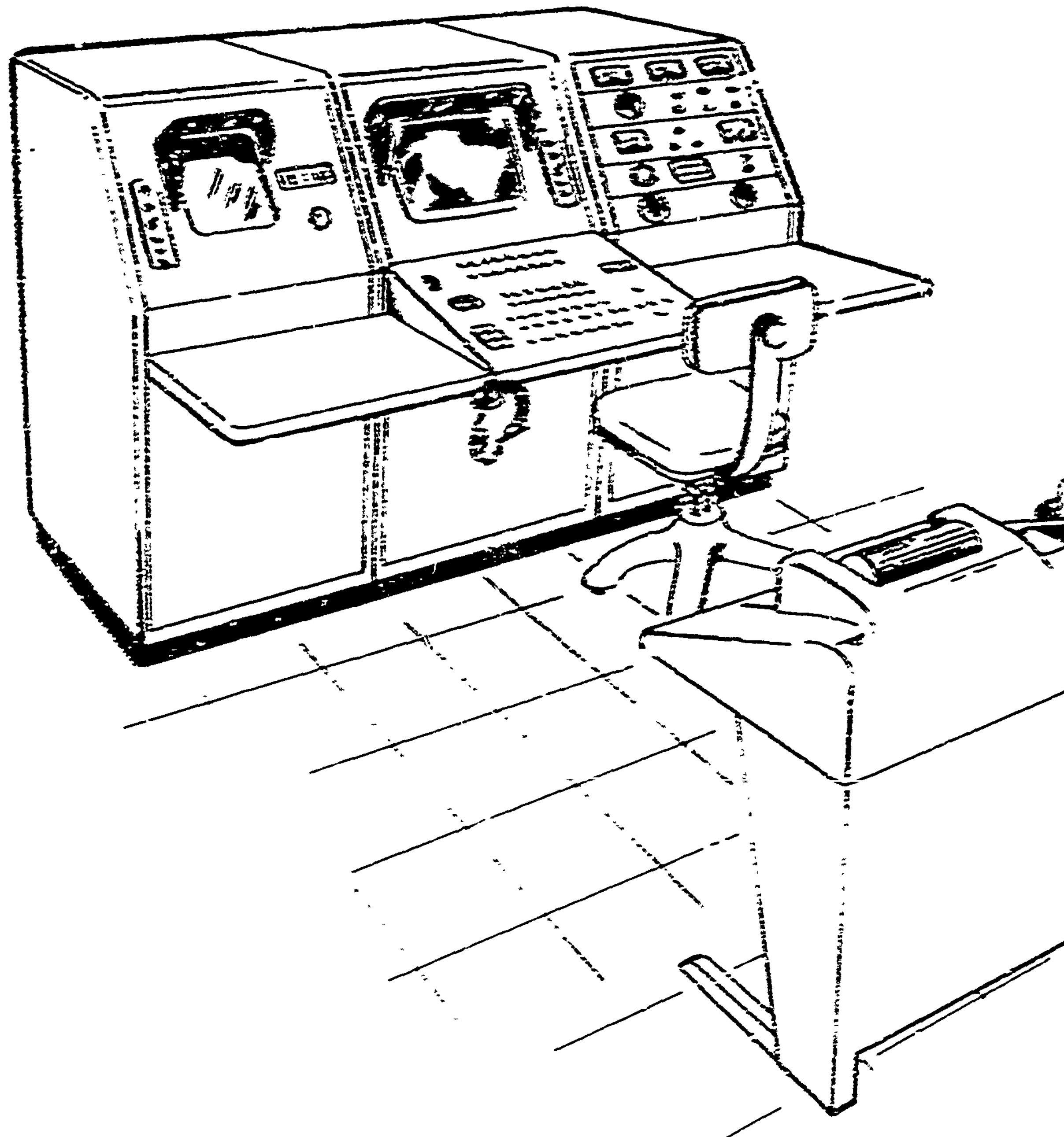
The status monitoring console position's primary concern involves the functions of equipment, link and circuit monitoring. These positions handle routine problems of operation and control. The number of these positions will vary with the size of the ATEC facility; typically, one for a small site, two for a medium size site and three for a large station. The quantity can also vary with the number of high priority circuits, thereby making the number of positions a function of the operational requirements of a particular facility

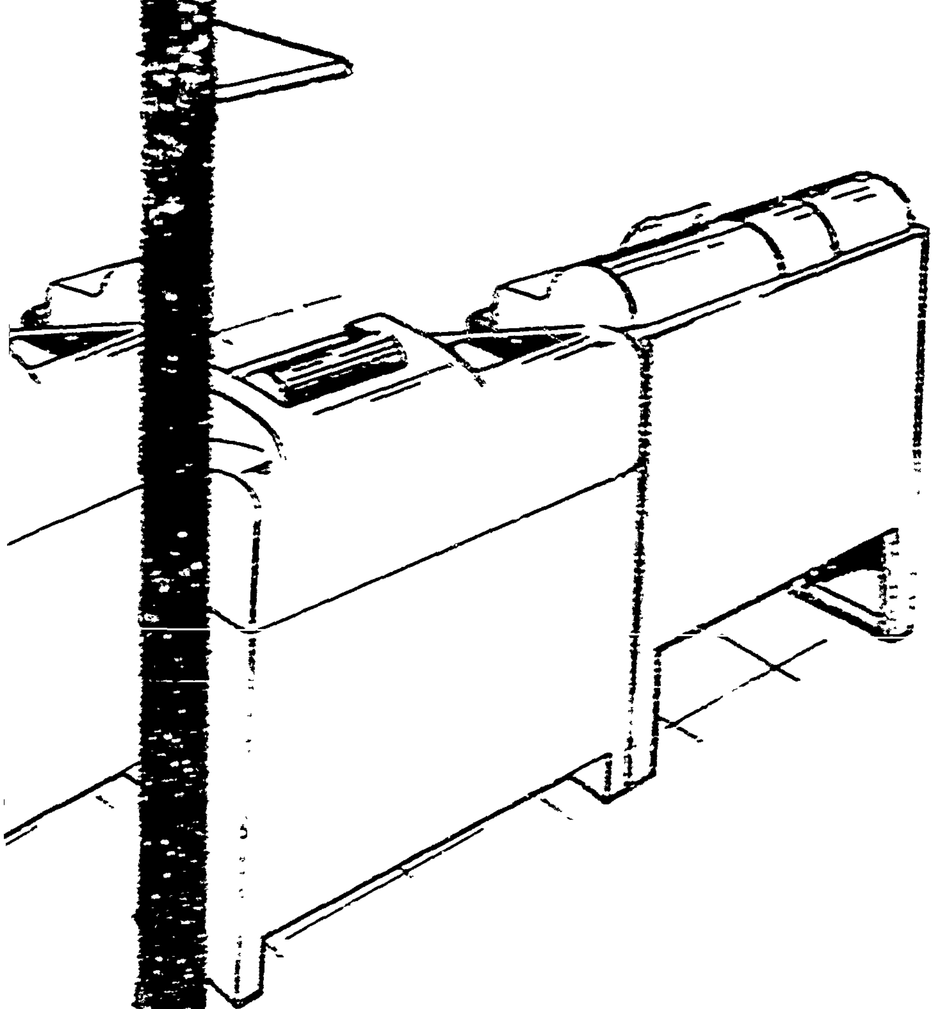
The quality control position evolved from requirements in DCAC 310-70-1 for quality monitoring of circuits, channels, links, and equipment, on a scheduled basis, to assure performance of these items. Typically, there will be only one of these positions at a large ATEC facility. There may not be a separate quality control position at a small or medium size site. This function can be combined with a status monitor position and will depend upon the operational requirement of the particular station.

The Central Control position encompasses the functions of both Central Control and system status monitoring. This is the supervisory position and the Central Controller directs the actions of all other controllers, from this console.

3.4.2 Status Monitoring Console Position

The display and control functional requirements for the status monitoring console position will be as recommended in Section XVI; namely, (a) static reference file, (b) interactive terminal, and (c) selective hard copy. In addition, the position will also be equipped with operational test equipment for normal Tech Control test functions and a teletypewriter set to be used for orderwire and monitoring purposes. The operational test equipment will provide the capability for both analog and digital testing and monitoring when the ATEC facility has both types of circuits. A typical status monitoring console position is depicted in Figure 16. The sit-down bay position, in the center, is the interactive terminal





B

FIGURE 16
TYPICAL STATUS
MONITORING CONSOLE POSITION

with raster display, alphanumeric keyboard, fixed and variable function keys, intercom, voice and teletypewriter orderwire selection, and handset and headset for voice orderwire and dial phone capability. In addition, audible and visual indications will be provided for Amber and Red conditions, with audible alarm disable and reset keys. The bay position on the left is the static reference file with display screen, slide selection control keys and GMT (Zulu time) digital clock. The bay on the right contains the audio and digital operational test equipment for circuit and channel analysis. The specific test equipment will include a data transmission test set, a distortion analyzer test set, an audio frequency signal generator, a level and noise measuring set, and a VU meter and monitor amplifier with loudspeaker. Auxiliary equipment, such as test jack selection switches, modulation rate converters and power supplies, will be contained at the bottom of the bay consoles.

The selective land copy and orderwire monitor teletypewriter sets will be positioned facing the bay position for operator convenient access. The ASCII ASR set, used for selective land copy, will provide interfaces with the alphanumeric terminal, and also act as a backup input device for the alphanumeric keyboard. The ITA #2 (International Telegraph Alp., No. 2, American Version, Baudot) ASR set will provide the necessary interfaces for teletypewriter orderwires to LOWCE, PTF's, TCF's and other ATEC's; however, in the case of other ATEC's, the ASCII ASR set could also be used if the communication channel can handle a 110 baud rate signal. Capability will be provided for modulation rate conversion with the ITA #2 ASR set. The Modulation Rate Converters (MRC) will be used to convert the speed of teletypewriter signals so that the status monitor operator will be able to talk on-line with LOWCE, PTF's and TCF's, or used to monitor teletypewriter channels under test at the required speed. Separate ITA #2 ASR sets will be provided at the digital patch facility for use as teletypewriter orderwire monitors, so that the status monitor position will not need to monitor the orderwire circuits. The ASR sets will also provide start function alarms to alert the operators by lighting a lamp at the orderwire selection keys.

3.4.3 Quality Control Console Position

The display and control functional requirements for the quality control console position will be the same as those specified in subparagraph 3.4.2 for the status monitor console position, except that this will also include more operational test equipment and teletypewriter sets for extended and more detailed testing and monitoring. The quality control console position will, for example, be provided with a VF channel multiparameter test set for fast checkout of audio circuits. A digital readout to an ASCII KSR set will provide tabulated data on the VF circuit or channel for frequency response, envelope delay, signal-to-noise ratio, frequency translation, phase jitter, nonlinear amplifier harmonic

distortion and loss or channel loss. A typical quality control console position is shown in Figure [illegible]. The description for the three bays on the left and the ASCII and ITA #2 [illegible] sets is the same as that in subparagraph 2.4.2. The bay position on the right contains an audio frequency signal generator, an envelope delay measuring set, a spectrum analyzer, a frequency selective voltmeter and a VF channel multiplex monitor test set. The ASCII [illegible] provides the input-output interfaces for the multiplex monitor test set. The two ITA #2 [illegible] sets provide for extended monitoring of teletypewriter circuits under test.

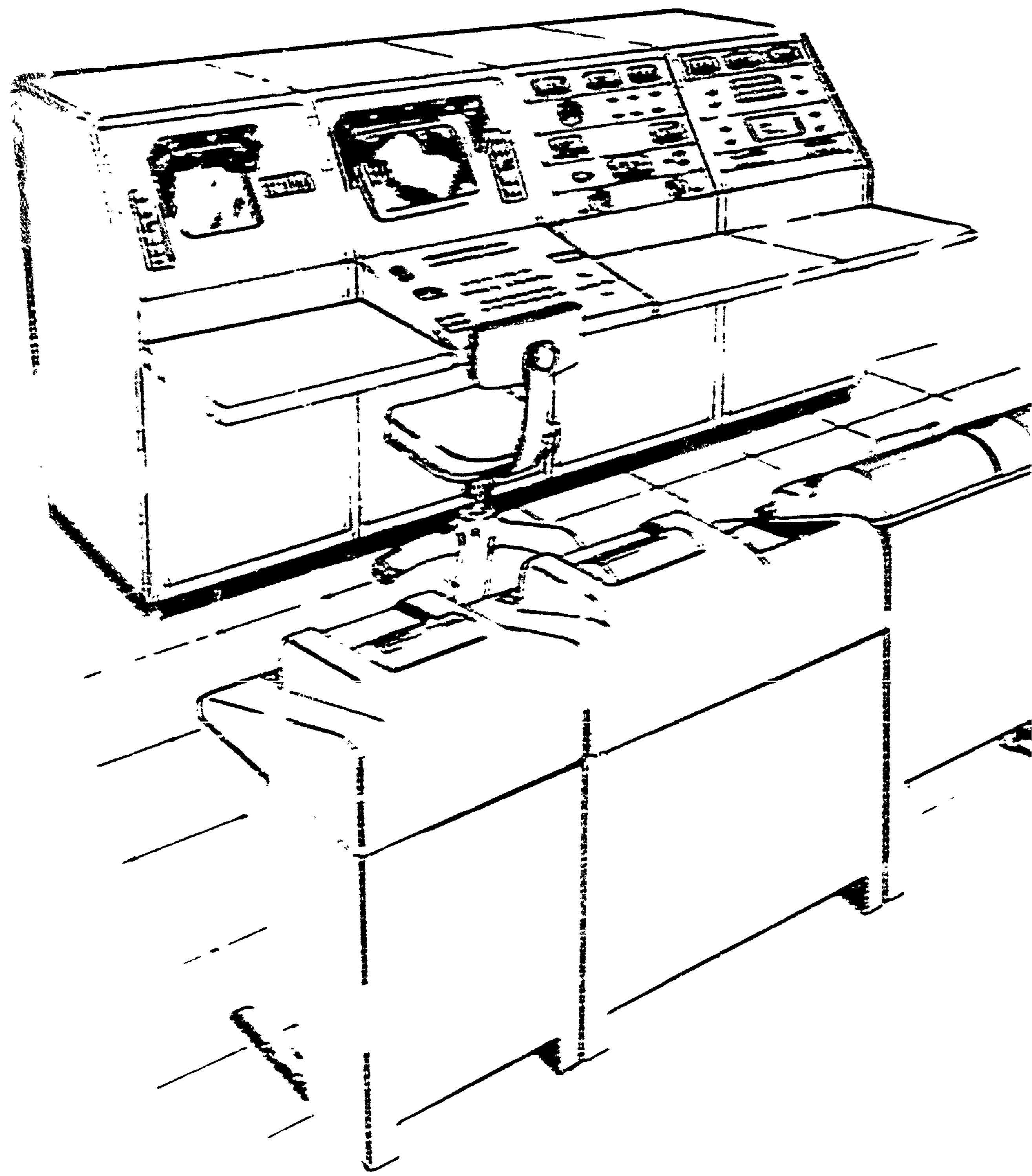
2.4.4 Central Control Console Position

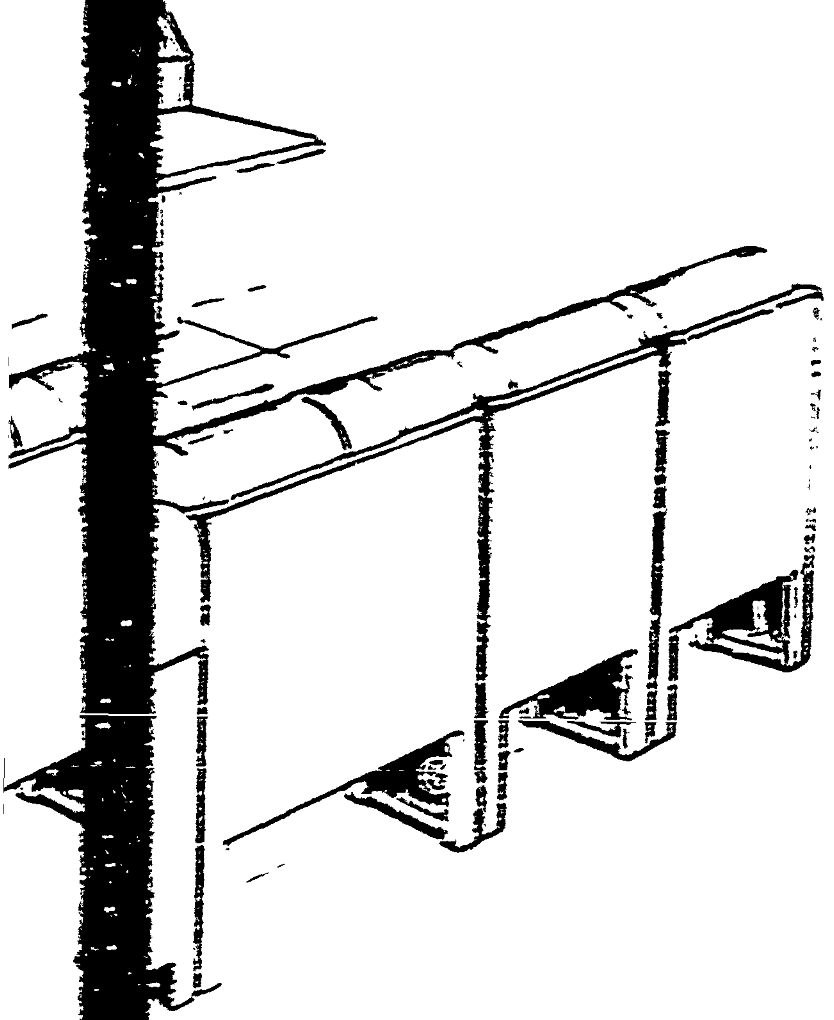
The display and control functional requirements for the Central Control console position will be as recommended in Section [illegible], namely, (a) static reference file, (b) inter-active terminal, and (c) selective hard copy. The position will also have a high speed teleprinter for fast readout of processor information and a teletypewriter set for orderwire and monitoring purposes. The operator will be capable of accessing digital and voice orderwires for coordination purposes. The intercom circuitry will also connect to the status monitor and quality control positions for supervision and technical coordination. A typical Central Control console position is portrayed in Figure [illegible]. The sit-down bay position on the left is the static reference file with display screen, slide selection control keys, and [illegible] (Julian time) digital clock. The bay position on the right is the interactive terminal with matrix display, alphanumeric keyboard, fixed and variable function keys, intercom, voice and teletypewriter orderwire selection; and handset and headset for voice orderwire and dial phone capability.

The selective hard copy, high speed printer and orderwire monitor teletypewriter sets will be situated facing the front of the console position. The ASCII [illegible] set used for selective hard copy will interface with the interactive terminal, and can also be used for inserting changes into the data-base. The high speed printer will be required for rapid readout from the processor of voluminous technical data, such as station and system status information. The ITA #2 [illegible] will be used for coordination over teletypewriter orderwires with users, [illegible]'s, [illegible]'s and other [illegible]'s. [illegible]'s will be required for interfacing with the several teletypewriter speeds in use by the various military services and civilian agencies.

2.5 [illegible]

The basic study applicable to this paragraph is in Section [illegible] of Volume [illegible] titled "Teletypewriter and Voice Orderwire Systems and Equipment." The following is a summary of these recommendations and the additional requirements which have evolved during system analysis.





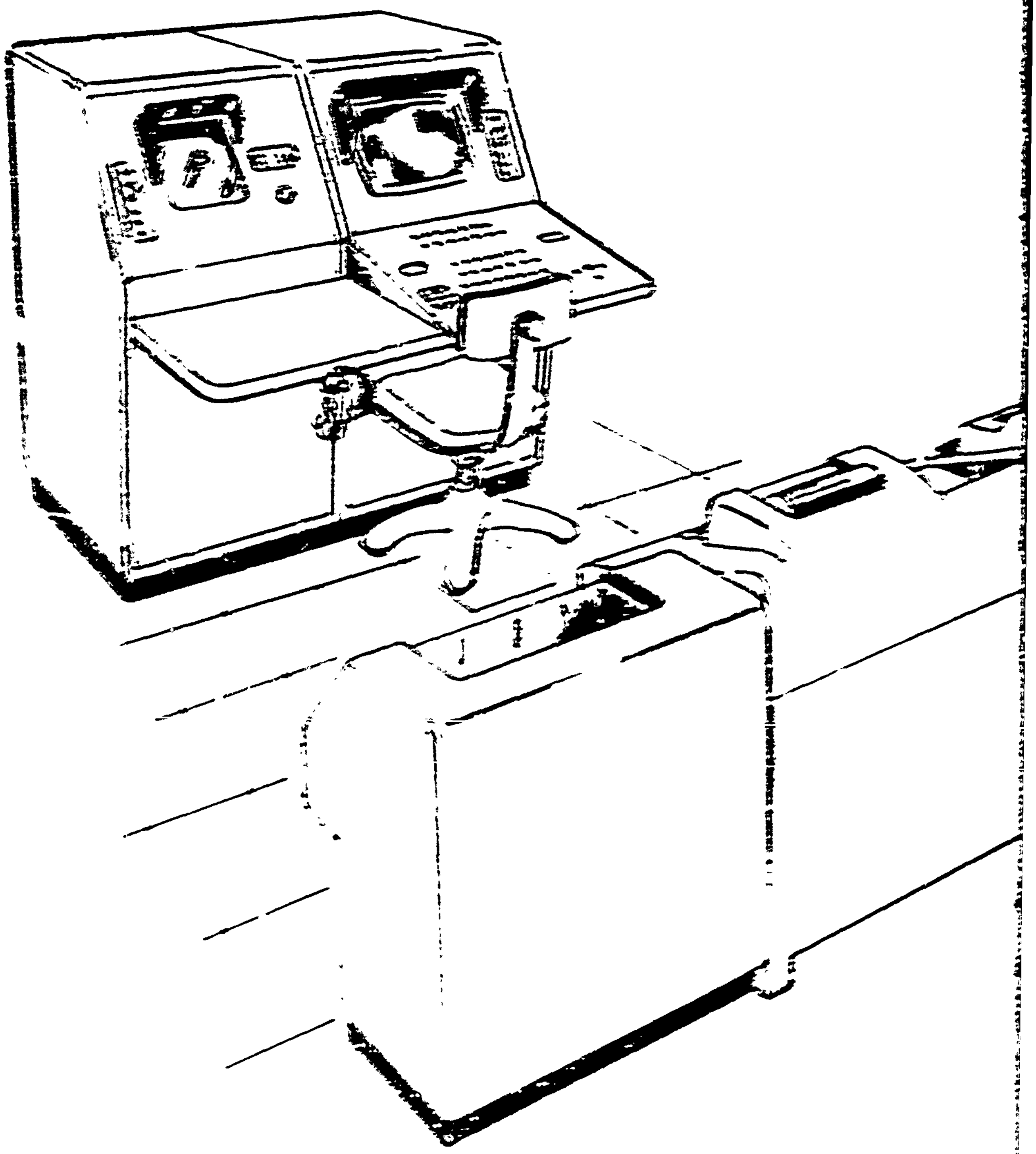
B

FIGURE [illegible]

TYPICAL DUAL[illegible]

CONTROL CONSOLE POSITION

[illegible]



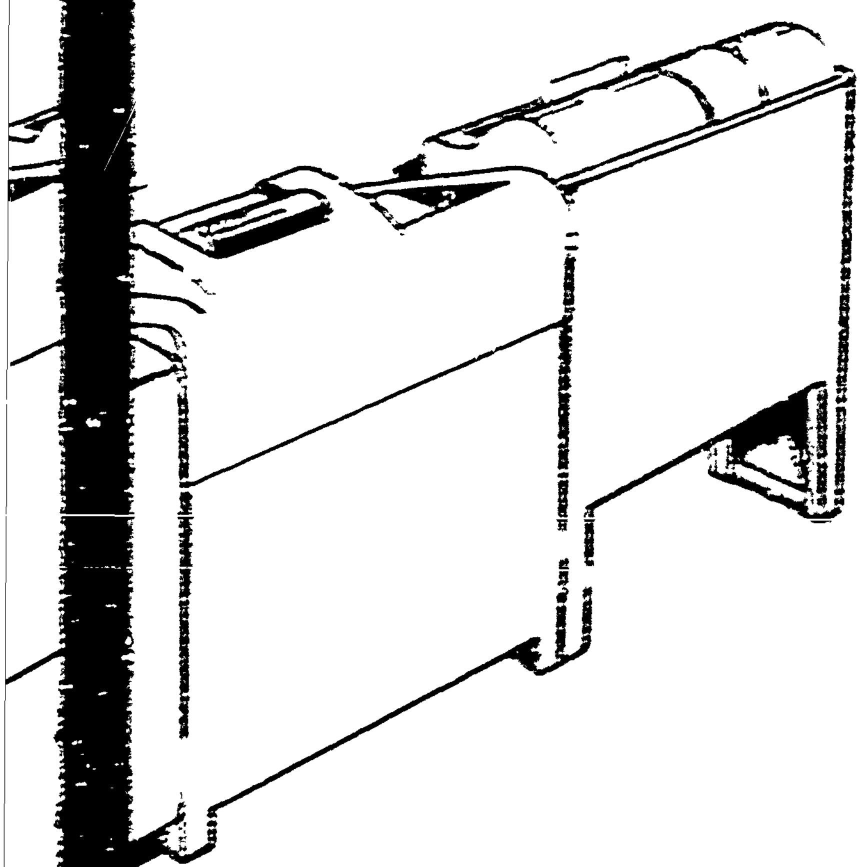


FIGURE 8
TYPICAL CENTRAL
CONTROL CONSOLE POSITION

3.5.1 Existing Orderwires

The orderwires presently in use by DCS facilities, as established by DCAC 310-70-1, provide for voice and/or teletypewriter communication from the TCF's to other TCF's, to certain user PTT's, and to sites providing communications channels, such as HF transmitter and receiver sites, LOS microwave and tropospheric scatter sites, satellite earth terminals, submarine cable terminals and commercial common carrier facilities. The orderwires are used for coordination in the restoration of circuits and correction of failed equipment, links and systems.

Teletypewriter loop or local orderwires are used when a TCF may have several PTT's or subordinate TCF's which require occasional use of an orderwire. Dedicated teletypewriter orderwires connect a TCF with other major TCF's, and in this category must also be included the teletypewriter orderwires carried on point-to-point HF ISB radio paths. These dedicated orderwires may further be grouped into those which are secure and those that are nonsecure. The quantity of either type will vary according to operational requirements and, necessarily, by the number and type of links controlled by a TCF.

Voice orderwires are also used extensively for coordination purposes between TCF's and also to PTT's and certain users. Since few, if any, are encrypted, the conversations passed are restricted to unclassified information and operational terminology. These Tech Control voice orderwires are normally dedicated circuits and occupy channels in the VF carrier multiplex of a radio link or are routed on cable pairs when the sites are nearby. For LOS and TROPO, a link orderwire is normally provided for maintenance purposes and occupies a portion of the baseband below the multiplex. In certain stations, this orderwire is available in Tech Control. The link orderwire is, however, a party-line and, therefore, requires operational discipline in its use. In some of the communications systems, an express orderwire has been added, in the service channel spectrum, which provides for selective two-digit calling either by DTMF or dial. With this system, an operator can establish a connection to the desired facility without using the "shout-down" or "ring-down" technique of a link orderwire. The express orderwire technique readily lends itself to Tech Control use; however, it was intended for maintenance as well as operational purposes. Where these express orderwires have been installed, as part of a wideband communication system, they have been extended into the Tech Control areas or facilities from the radio equipment areas or facilities. The express orderwire method combines the best features of a dedicated orderwire and central office. The operator has access to several dedicated express orderwire trunks and the trunks can be shared among many sites and facilities. The trunks can be further segregated into networks providing unrestricted access in a local area plus and dial-through capability into other area networks.

The link and equipment noise contributions are provided in the below multiplex baseband or service channel spectrum. This spectrum varies with wideband systems and equipments, and the availability of service channel bandwidth depends upon: (a) the modulation plan used and (b) the location of the service channel in the radio baseband spectrum. Taking the first premise, the multiplex baseband can start, on the lower frequency end, at 12 kHz for "A" plan or at 60 kHz for "B" plan. Therefore, the amount of below multiplex baseband available for the service channel may be either from 0 to 12 kHz or 0 to 60 kHz. The location of the service channel in the radio baseband spectrum can also vary among communication systems. The use of below multiplex baseband for the service channel can be limited as indicated above, however, some of the newer equipment and systems have been installed with the service channel above the multiplex baseband higher frequency end. This scheme provides for unrestricted bandwidth, and the service channel is also less noisy at this point of the radio baseband spectrum. In addition, any harmonic distortion products, generated in the service channel, will not contribute to the noise in the multiplex baseband signal as they would if the service channel were located in the below multiplex baseband spectrum. The major consideration with an above multiplex baseband service channel is that it must be engineered, for the system and equipment, to place the service channel within the bandwidth of the radio baseband spectrum. Any later changes, due to expansion of groups or supergroups in the multiplex baseband, would require relocating the service channel to a higher frequency range in the radio baseband spectrum. This, however, can be overcome if the frequency determining elements of the service channel are modular and can be readily replaced to facilitate a change of this type.

3.5.2 Coordination Requirements

The coordination requirements for the ATEC facility will necessarily include existing voice and teletypewriter orderwires and, in addition, will combine these, along with an intercom subsystem, into a compatible orderwire system to facilitate console operation. Operation of the ATEC system (and within an ATEC facility) will require coordination among the console operators; between the console operators and other elements within and nearby to the ATEC; between the console operators and communication users and suppliers; and between the ATEC facility and other ATEC's, TCF's and PTT's.

The console operator positions include status monitoring, quality control and Central Control. Coordination among these positions requires unrestricted access. Therefore, a conference bridging scheme with two or three buses depending on the number of consoles will be required as part of the intercom subsystem. Console operator coordination will also be required with supervisory personnel and key equipment locations such as patch bays, VF

carrier multiplex, radio equipment, and the distributing frame. Coordination with these locations and personnel, in addition to selected operational, support and administrative offices, will be required via the intercom subsystem.

The voice and teletypewriter orderwires will require access by the console operators and certain other selected operational and maintenance personnel. These orderwires normally provide the means for coordinating with TCF's, PTF's, communication suppliers, and selected users. The console operators will require a means for selecting and signaling, and being signaled by, the voice orderwires. A means must also be provided to select access to any of the nonsecure teletypewriter orderwires. Upon selection, the nonsecure orderwire circuit will be connected to a teletypewriter, at the console position, via a modulation rate converter which will provide compatibility for operating at any of the standard speeds. The code used for orderwires should continue to be the International Telegraph Alphabet #2, (ITA #2), American Version, due to the fact that about all teletypewriter machines, now in use for orderwires, use this code, and replacing all existing machines with ASCII (American Standard Code for Information Interchange) teleprinters is not cost-effective. There is, however, a requirement to facilitate connection of the ASCII machine, at each console position, to circuits which may have ASCII terminals.

The status information for the ATEC facility will be contained in the processor data storage. This data storage will consist of random access mass storage and magnetic tape transports which will accept information generated by the processor and the console operators. By themselves, the individual pieces of information are not classified but the entire store, or for example a report rendered on outages, link failures, system failures, etc., could be considered as classified information. It could be considered classified because it presents a compilation of capability and effectiveness for a particular facility and/or the associated communications systems. This information is also volatile but, taken at different times, a historical record could be built up to determine which telecommunications systems are the most troublesome or vulnerable.

The present TCF's do not, by and large, have a general service teletypewriter terminal installed for transmission of DCA and O&M reports. The reports are generated, typed on message forms, signed off by the responsible releasing authorities and handcarried to a message center. The message center may be in the same building or elsewhere on base. This is a cumbersome and tedious method for generation and transmission of such reports. The ATEC facility, in order to generate and transmit timely reports, will require an AUTODIN Mode II terminal. This terminal will provide a circuit to the nearest AUTODIN switch for routing of the reports to the proper agencies and offices.

The reports will be composed and generated by the Central Control position which will obtain the proper data from the tape transport stores and, using a stored report format, generate a hard copy and paper tape copy. The hard copy will be used for gaining release of the report for transmission and for maintaining a file copy of such reports. The paper tape will then be used for transmitting the report via the AUTODIN terminal. This method of handling the transmission of status information will also be adaptable for any size ATEC since the speed of operation of the AUTODIN terminal can be selected to meet operational requirements. The AUTODIN terminal will also provide a receive terminal for direct reception of messages from DCA and O&M agencies. This again will enhance the ATEC operation by timely receipt of operational direction messages.

In addition to all previous requirements for coordination, there will exist a need for processor-to-processor coordination. This coordination will be necessary for passing data information concerning link, trunk and circuit outages: restoral action such as trunk and circuit reroutes; and normalization of trunks and circuits to their assigned profiles. This information will be used to provide a near real-time data-base update for ATEC's so that any contemplated reroute via the station reporting an outage will take into consideration the condition of the links, trunks and circuits at that time.

3.5.3 Orderwire Recording

The hard copy of orderwire teleprinters has long been used to provide a record of events and as backup information to station operating logs. This practice will be continued in the ATEC facility since it is much more cost-effective than providing digital magnetic tape recorders as separate paper tape monitor banks. The teletypewriter orderwires will have teleprinters on-line continuously for each orderwire circuit. These teleprinters will be located in the area of the digital (DC) patch bays to enable their being scanned by Tech Control personnel at the patch bays and to facilitate station operation in a fall-back mode.

Voice orderwire recording will be accomplished through the use of magnetic tape recorders. Section XVIII in Volume II recommends use of multiple track tape recorders in large and certain medium-sized ATEC facilities and individual dual-track tape recorders, at each console position for small and some medium-sized stations. The system requirements for voice recording in an ATEC would not require the use of multiple track tape recorders since the voice orderwires are not critical in the respect of air-to-ground recording of all transmissions. In addition, the requirements for standardization are better fulfilled by provision of individual cassette-type, dual-track, tape recorders for each console position. The dual-track recorder would store both sides of the conversation on one track and record the time, by the minute, on the other track.

The tape recorder would only be activated upon access of the orderwire by the operator; i.e. the off-hook condition. The cassettes should be replaced at the start of each shift and during each shift as required. The cassettes could then be marked with the date, position and operators and then stored in a centralized control area. This method of recording would allow immediate selection and review of specific stored information or events by selecting the proper cassette. After a predetermined period of time, such as one or two weeks, the cassette could be reused.

Recording of processor-to-processor transmissions should be provided by maintaining the hard copy printouts of such data from the high speed printer, or historical records maintained by the processing hardware. The Central Control operator would be responsible for review and release of the data and a fast printout record can be made and stored for an appropriate period of time.

3.5.4 Orderwire Subsystems

The recommendations made in the study task on "Teletypewriter and Voice Orderwire Systems and Equipment," Section XVIII in Volume II of this report, have identified four orderwire subsystems to be implemented for the ATEC system. The four subsystems are: (a) Intercomplex, (b) Intrafacility, (c) Intersite, and (d) Intralink. The following paragraphs summarize the functional and operational requirements of these subsystems and include considerations developed as a result of system analysis.

a. Intercomplex

The intercomplex orderwire subsystem would extend existing express orderwire networks in one geographical area to similar networks in adjacent geographical areas, through use of existing interarea orderwire circuits. Where such interarea orderwire circuits do not exist, the AUTOVON network would be used. This, therefore, requires that the ATEC facility be provided with one or more AUTOVON user drops, paralleled at the console positions, depending on operational requirements, to augment the intercomplex orderwire subsystem. This capability will enhance fault isolation and correction.

b. Intrafacility

The intrafacility orderwire subsystem would provide intercom voice service to important locations within the ATEC facility, to collocated

facilities, and to nearby offices and facilities. The use of intercom will facilitate sit-down console operation by providing the console operators with communications access to the operational, maintenance, equipment, supervisory and support areas within and around the ATEC facility.

c. Intersite

The intersite orderwire subsystem would combine existing dedicated voice and nonsecure teletypewriter orderwires to enable access from the console positions. These dedicated orderwires connect to communications sites such as: HF Transmitter and Receiver sites, LOS and TROPO sites, Commercial Common Carriers, and subordinate TCF's and PTF's. The orderwires to these sites may be voice, or teletypewriter, or both; so that the ATEC console operators will require access via appropriate terminal devices. The study task report recommended connection of these orderwires into the intercomplex orderwire subsystem. This feature should be provided so that the console operator makes the desired connection and, in turn, has override capability to access the connected orderwires when necessary.

d. Intralink

The intralink orderwire subsystem would extend existing link orderwires from LOS and TROPO radio equipment (when in collocated or nearby areas) to the console positions. In addition, other link orderwires such as HF voice and/or nonsecure teletypewriter orderwires and orderwires on cable circuits would be combined for selective access by the ATEC operators.

All orderwire circuits will be required to appear in the appropriate patch bays to enable patch-through capability and also for testing and reroute action if necessary. Duplicate terminal capability should be provided at the patch bays to facilititate operation in the fall-back mode.

In addition to the orderwire subsystems, the console operators in the ATEC facility will require access to the local telephone system. One or more subscriber drops should be paralleled to the console positions. This is necessary because there are usually a number of users which do not have orderwire capability and, therefore, will contact the ATEC through the local telephone network.

3.6 Special Considerations

This category considers those requirement areas, of the ATEC facility, that are of subjective nature and are related to the ATEC system in that they provide requirements for application and implementation in technical areas previously discussed.

3.6.1 Line Conditioning

The contractual requirement for line conditioning, in the ATEC facility, is that automatic line conditioning equipment is essential and consideration of this area should include regenerative, adaptive and passive approaches and echo suppressors. Section XIX, Line Conditioning, in Volume II, provides an analysis of state-of-the-art methods used in line conditioning. While it may be concluded that automatic line conditioning equipment is essentially desirable in the ATEC facility, the results of the evaluation are that automatic line conditioning is, at present and in the foreseeable future, neither technically effective nor cost-effective. The use of automatic equalizers is now only a realization in a few types of modems - those which provide for operation at 4800, 6?00, 7200, or 9600 bps. The design of the automatic equalizer is integral with the modulation or signal plan employed by the modem. The manufacturers making these high speed modems have their own proprietary designs and no two are the same. To make use of automatic equalization at an ATEC facility would therefore infer that the modems would be located at the ATEC. However, this is not the case in the present situation. The modems are located at the user terminals and provide for end-to-end equalization. From a systems standpoint, the ATEC, ideally, should have the capability for providing automated equalizers on channels which could be automatically set upon application of a test or probe signal. Although this is technically effective, it is not cost-effective since it would involve new hardware design and development. The present method of providing line conditioning equipment, on certain telecommunications channels, at a tech control facility, could be greatly enhanced through introduction of the multiparameter test set. The preponderant problem with the present method of providing equalization at a tech control facility is that the devices have limited compensating capability and the tech controller does not know how much harm or good is being done to the signal in question at any particular moment. While the multiparameter test set will not entirely eliminate the problem, as stated, it will provide the tech controller with a valuable tool to be used in channel investigation and, in the case of quality control, to provide assurance that the channel is meeting established specifications and will do so in a few minutes rather than in the 10 to 30 minutes now required for testing.

3.6.2 Central Station Clock

The contractual requirement for central station clock, in the ATEC facility, is that the requirement for a central station clock must be recognized and evaluated for the creation of a worldwide synchronized station clock system. Section XX, Central Station Clock, in Volume II, presents an analysis of present and anticipated future capabilities in this area. The anticipated ATEC System is also analyzed relative to its specific clock requirements. It is concluded therein that the initial as well as the eventual clock requirements of ATEC must be consistent with the clock requirements of the communications facilities which it is to control. That is, to the greatest extent possible, the sources of standard frequency, standard timing and standard time for ATEC must be the same as those for the associated communications equipments and facilities. This approach will result in minimum translation errors, sampling errors, or reference errors being introduced by the ATEC equipments and techniques employed for monitoring and testing. Hence, as central station clock is introduced and implemented on a worldwide basis, for use by communications networks and facilities, it will be automatically employed by the ATEC System.

It should be clear from the above discussion that a central clock will not be introduced solely for ATEC use. Various frequency and time sources are required for an ATEC facility in such equipments as distortion measuring sets, transmission measuring test sets, VF channel analyzers, channel break out monitors and other similar monitoring and testing devices. It is necessary, also, to include a real time clock as a source of both Zulu time and local time for processor use as well as for use by operational personnel in time tagging and logging activities. These various individual sources will suffice in accuracy and stability, but can be slaved to, or replaced by, outputs from the central station clock; when it is added as a result of communications requirements.

3.6.3 Standardization and Modularization

The contractual requirement for standardization and modularization, in the ATEC facility, is quoted as follows:

> "Standardization must include the standardization of functions and parameters as well as equipment. This does not mean that the same quantity of equipment will be placed at each installation, but rather that if a device is required, it will be the same device everywhere, performing the same functions and measuring the same parameters. All equipment and consoles will be modularized for all tech controls. In addition, modularity, like standardization, must also be considered on a functional basis. For example, at large complex facilities,

control must be exercised over analog <u>and</u> digital communications. (Note: Control over analog and digital functions does not mean that analog and digital functions must be physically combined nor does it mean a requirement for analog control to handle anything but black information.) However, at smaller tech control facilities, perhaps <u>only</u> analog <u>or</u> digital control may be required. Thus, equipment modularity (i.e., the building block concept) is mandatory to permit a smaller number of modules to be used on the smaller facility and <u>functional design</u> modularity as required so that the modules which are used are only those needed to service the facility."

The requirements for standardization and modularization have been highlighted as design goals throughout the course of the individual study tasks. Link, equipment, circuit and system monitoring have used various sizes of tech controls as models in developing hardware requirements. Central control, telemetry, automated patching and processor requirements have been formulated to provide for their usage in various configurations. Human factors has been considered, along with standardization and modularization, in the design requirements for display and control. The results of each of these study tasks are documented in Volume II.

The requirement for standardization of functions and parameters, as well as equipment has also been considered in system design of the typical ATEC facility. This typical ATEC facility must be small, medium or large depending on quantities and types of circuits and operational requirements. A large ATEC facility would conceivably have all types of modules and functional requirements specified for the ATEC system, while a medium or small ATEC facility would only have those modules specified for certain operational capabilities. It must be capable of coordination and control with users of communications services (including AUTODIN and AUTOVON) and with sites providing telecommunications media (including LOS microwave, tropospheric scatter, satellite earth terminal, submarine cable and/or local or remote HF transmitter and receiver sites). Coordination and control, with any of these many types of facilities, requires that operational functions be standardized in the ATEC facility to enable the operators to view the users and communications links as a network. This network handles a variety of circuits and signals with differing priorities among each type. The present tech control facilities have standardized handling of the circuits by logically dividing them into digital and audio categories and placing minimum performance requirements on the communications channels. The ATEC facility continues this standardized method of treating circuits and improves upon it through use of automated and modularized equipment.

The functional method of testing and monitoring digital and audio circuits will be essentially the same whether the circuit is routed via cable and/or radio paths. The performance requirements for the circuits may vary, based on operating characteristics, but the functional design of the hardware for performance assessment will be standardized. The equipment/link sensors, as well as the circuit status monitoring equipment, have been conceived using modular concepts and standardized in function so that they could be applicable in any type communications facility. Their modularity promotes expansion and contraction based on operational requirements which may vary significantly in the period of a year or less.

With the present trend toward high-speed digital communications for both voice and data, it appears that the DCS may eventually evolve into an all-digital network but, for the present and near-future, a hybrid network of analog channels carrying voice and data is foreseen. Therefore, the functional requirements recommended for the ATEC facility have been standardized along these lines and modularized so that a particular site may handle only analog or digital signals, or both.

The requirement for functional design standardization is most pertinent when considering the man-machine interface. The operators need information presented to them in a fashion that precludes misunderstanding and yet is concise enough to minimize processor memory space. The command instructions to be entered into the processor or control unit by the operator must also be concise and yet understandable by man and machine alike. Therefore, the operational program and data store for the processor must be standardized in a basic language and must also be modular so that various sized ATEC facilities may have only those portions of the program that are applicable for operations at that facility.

Standardization with respect to parts selection criteria will be required as part of the individual equipment specifications for any new items. The requirement will be in accordance with MIL-E-4158D, paragraph 3.3.1.2. Implementation of these standardization requirements aimed at ease of maintenance and economical supply support, through minimization of nonstandard parts, will be achieved by evaluation during the equipment design and implementation phase. This will be accomplished by having copies of advance material lists, material requisitions and Bills of Materials, reviewed and analyzed with respect to standardization requirements of MIL-E-4158D.

3.6.4 Reliability and Maintainability

The contractual requirements for Reliability and Maintainability (R&M) are as specified in CDRL item B006 and B007, respectively. The result of these requirements is contained in a document titled: "ATEC Reliability and Maintainability Analysis"; which will be submitted as a separate data item. R&M analysis is to be provided for each individual equipment and for the overall integrated

configuration identified in this phase. Quantitative evaluations for Mean-Time-Between-Failure (MTBF) and Mean-Time-To-Repair (MTTR) of each equipment will be included in each Contract End Item (CEI) Detail Specification, Part I, Prime Equipment. R&M requirements, and definitions of the conditions under which the requirements are to be met, will be included in applicable paragraphs of the system specification, CDRL Item B002.

3.5.5 Transportability

The design of the ATEC facility and equipment will be required to take into consideration transportability and recoverability. Consideration has been given to modular design for all elements of the ATEC facility which will enhance the capabilities for transportability and recoverability. Installation design of all items for the ATEC facility will be required to consider recoverability of assets in the instance where removal or relocation becomes necessary. Requirements for transportability, which are common to all system equipment to permit employment, deployment and logistic support, will be stated in the system specification.

3.5.6 Graceful Degradation and Manual Back-up Operation

The ATEC facility has been designed such that in the event of a failure of ATEC elements or degradation of ATEC element performance, a graceful degradation will take place with eventual fall-back to the completely manual mode of TCF operation.

The general overall modular design of the ATEC facility directly supports this objective. The modularity relative to sensors, scanners, analyzers, monitor/test buses and displays specifically contributes to the prevention of catastrophic ATEC facility failures. The only significant vulnerability may be attributed to the employment of a single processor and the use of switching for patching purposes. However, the switching is completely redundant with the manual patching which is being updated in the ATEC facility. The processor can be completely divorced from the system for a short time provided that sufficient data (normally retained in memory and updated by the processor) is maintained current in the form of hard copy printouts.

Failures of a specific sensor, or of a group of sensors (by virtue of failure of a common module), will only affect the monitoring of a limited number of equipments or circuits. The individual sensors are to be designed such that a failure of the sensors will not affect the equipment or signal being monitored. Also, a certain degree of redundancy exists relative to monitoring; e.g., circuit monitoring will also detect most equipment failures, although less effectively. Similarly the failure of a single scanner or analyzer will only affect the monitoring of those

parameters with which it is associated. Here again, a certain amount of inherent redundancy will permit detection of significant and definite failures. For example, scanning of receive channels at baseband can be accomplished (when required) in addition to the normal scanning of transmit channels at baseband. Likewise, scanning of transmit channels (incoming channels) at the user drop can be accomplished (when required) in addition to the normal scanning of receive channels (outgoing channels) at the user drop. Hence, failures which affect both the send and the receive sides of a circuit, as well as failures which are external to the ATEC facility can be detected as long as either baseband circuit monitoring or user drop circuit monitoring is operational. Also, failures which affect only receive channels can be detected as long as user drop circuit monitoring is operational, and failures which affect only transmit channels can be detected as long as baseband circuit monitoring is operational.

Two other provisions for fall-back operation include: (a) The capability for manual operation of the User VF Channel Selector and associated units (for monitoring outgoing, or transmit, VF channels at the user drop), and (b) The independent operation of the Automatic Digital Circuit Analyzer (for monitoring outgoing, or transmit, DC channels at the user drop). The User VF Channel Selector and associated units (VF channel analyzers and VF channel scanners) can be manually (via pushbutton) stepped through all of the circuits with which they are associated. They provide a front panel readout of the identity of the circuit being monitored, the actual analog level from the sensor and an indication (via lamp) as to whether speech is present or not. These readings can then be manually compared to a previously prepared list of circuits, circuit types (speech or analog data) and red threshold values, to establish circuit performance. The Automatic Digital Circuit Analyzer is capable of free running (independent of processor control) operation and will provide direct readouts of circuit status via a teletypewriter (page copy).

In addition to the above capabilities, the various maintenance indicators on actual communications equipment cabinets will still be available for operator monitoring. In fact, these indicators and alarms should be monitored more conscientiously during ATEC degradations or failures. Also, as newer equipment designs are introduced, by way of new system installations or system upgradings, it is expected that far better fault detection and isolation (via indicator) to the Lowest Replaceable Module (LRM), will be included.

Access to individual circuits for monitoring, as well as testing, can also be achieved via the various monitor/test buses. Such access is normally accomplished by the processor, but in the event of processor failure, access can be accomplished by manual patching of the desired circuit monitor jack to the monitor/test trunk appearance at the patch bay. These monitor/test trunks terminate at the Status Monitoring Consoles and at the Quality Control Console where the desired measuring instruments can be connected.

Improved patch panels which are being brought into the ATEC facility design also serve as a key element in the manual, back-up mode of operation. These patch panels provide the capability, and complete flexibility, for restoring and rerouting. The required indicator lights, when illuminated, identify those jack sets which are effectively patched by switching. The switching is designed such that all existing connections are retained (without change) in the event of any associated failure, i.e., failure of switching equipment, processor, or power. A battery, or no-break power system, is specifically required for the switch connections and their associated indicators. In the event of processor failure, the Master Station Log and/or the individual activities logs will provide the details of these existing patches. It should also be noted that the patching/switching has been designed such that a manual patch (via patch cord) can be accomplished even though the appearances are already switched (indicators are illuminated). Hence, in the event of failure, connections that are already established by switching can be reconfigured or reconnected by manual patching. Also, all jack sets will include monitor jacks to permit monitoring and testing, particularly in this manual or fall-back mode of operation. These monitor jacks can be accessed via monitoring equipments either directly at the patch bays, or via the monitor/test trunks to the consoles, as described above. The orderwire equipments and monitor printers presently located in the patching area also further facilitate this manual mode of operation. Other means of coordination (communication) among operator positions, and with maintenance and management elements, as well as with other facilities (ATEC, TCF, User) will include intercom and orderwire capabilities which will not depend upon the processor or other ATEC elements for operation. This is of utmost importance in the event of processor or ATEC element failures.

The operator positions, or consoles, which are provided for: Status Monitoring, Quality Control, and Central Control, are all basically similar. In fact they all employ identical interactive terminals (CRT display and keyboard), rear projection slide viewers, teletypewriter sets, test buses, and intercom and orderwire units. The only major differences are: (1) The more extensive test equipments at the Quality Control position, (2) The lack of test equipments and test buses at the Central Control position, and (3) The high-speed printer at the Central Control position. Also, all positions are connected to the processor in the same manner, and are addressed by the processor in accordance with the identity provided to it by the position. Hence, any position can essentially act as any other position (upon so identifying itself) or as any other two positions (again by proper identification). Therefore, a failure or taking out-of-service of one position has only the ill effect of increasing the workload at another position.

A teletypewriter provided at each position can also take the place of the CRT and keyboard, thereby providing emergency back-up directly at that position. This mode of operation is achieved simply by positioning a switch which results in the connection of the teletypewriter directly to the processor effectively bypassing the interactive terminal (CRT display, keyboard and associated processor interface unit). Hence, operation of the position continues although at a slower rate. Overflow for this position can be directed to another position.

Reporting and record keeping can also be accomplished via manual methods. The teletypewriter associated with each operator position, as described above, can be employed for generation of records and of reports. In fact, with only the interactive terminal and its associated teletypewriter operational, records or reports can be composed on the CRT display via its associated keyboard and the result transferred directly to the teletypewriter for both page copy and paper tape copy. Also, recent records and reports should always be retained in hard copy form so that in the event of an AYEC failure, reference can be made to this copy to facilitate the preparation of further required records and reports. The reports, so generated, can be transmitted via normal methods, or hand-carried as necessary to achieve ultimate delivery.

Therefore, although much slower and consuming much more manpower, the tech control operations will continue in a fall-back or manual mode if and when such an unfortunate requirement should develop.

3.7 Support Requirements

The support requirements for the ATEC facility include: electrical power, environmental conditions, electromagnetic compatibility, training, and quality assurance provisions. The following paragraphs provide the requirements for each of these topics and their relation to the ATEC facility.

3.7.1 Power

The contractual requirement for the ATEC facility electrical power is that the system is to be designed to comply with the criteria of MIL-E-4158D. Paragraph 3.2.3.2.3, Electrical, of MIL-E-4158D specifies, in attendant subparagraphs, requirements for electrical power source and equipment design considerations. Since the ATEC facility must be capable of being installed at military sites around the world, the requirement for AC power source voltage must be adaptive to existing electrical power at these sites; whether commercial or base supplied. The requirement for AC equipment operation will usually be 115V, 1ø but to establish bounds for equipment specification purposes the requirement will normally be stated that the equipment is to operate on 115V, ± 10%, 1ø, 50 - 60 Hz, ± 5%. This is in line with most commercial applications and off-the-shelf equipment; however, the individual equipment specifications will still govern and an analysis must be made at the time of procurement to decide whether a different AC operating voltage characteristic is justified.

For the ATEC facility, which will include electronic equipment, data processing equipment, mass memory devices vital intercommunication and orderwire terminal units (including crypto for secure teletypewriter orderwires), and telemetry terminals handling and controlling remote terminal units, it is imperative that uninterrupted operation be a requirement. This requirement can be met in several ways. One would be to build-in the necessary uninterrupted power generating devices, (i.e., rectifier-chargers and battery banks) as part of certain equipment. This would satisfy the requirements of MIL-E-4158D, but does not satisfy the requirement of uninterrupted operation for the ATEC facility as it is functionally conceived. Another consideration is that some equipment requires AC power exclusively for operation so that use of battery banks would not suffice in these cases. The best method of assuring uninterrupted operation for the ATEC facility is the provision of a uninterrupted (no-break) AC power source to supply the technical AC power load.

Many major TCF's (and therefore candidate sites for ATEC facilities) now have rotary type no-break power units installed and supplying (or paralleling) the technical AC power load. For these sites, an evaluation would have to be made, by a field survey, to determine the acceptability and capacity of the no-break unit for use with the ATEC facility to be installed. For TCF's which have no uninterrupted power source (or the no-break unit is found to be inadequte) an AC-DC-AC

conversion no-break unit is recommended. This uninterrupted power system consists of AC to DC rectifiers, fed by commercial or base power, feeding (in parallel) a battery bank and motor-generator sets for DC to AC conversion. The AC is then fed to the AC tech power panels within the ATEC. This AC no-break system is the most reliable known and would give the ATEC facility at least 15 minutes of operation, off the battery bank, upon failure of the primary power source. This is adequate time to activate the auxiliary power generators normally provided for comm facilities which would then feed AC power to the rectifiers of the no-break system until restoration of commercial or base power. The isolation of the technical AC power load from the primary power source, through the use of battery banks (which may be considered a static flywheel) also satisfies the requirements of MIL-E-4158D for operation through periods of primary power fluctuation. This also means that commercial off-the-shelf equipment can be used in the ATEC without imposing costly redesign to meet the rigid specifications for transient state, power interruption and power outage.

Consideration must also be given to not only operating under the conditions mentioned above, but also to knowing the condition of the primary power source; i.e., the primary power service delivered to the ATEC facility. Monitoring will be required for voltage and frequency of the primary power to detect variations which might cause other problems. In addition, monitoring of this type should also be done at remote and local sites providing telecommunications media. The effects of primary power variation on HF, tropo and LOS radio equipment can result in communications channel perturbations which could ordinarily be ascribed to the communications equipment.

3.7.2 Environmental

The environmental service condition requirements for the ATEC facility will be essentially those which are normally provided for a fixed plant electronics installation. The following paragraphs provide a discussion of the various conditions and their relation to the ATEC facility.

The climatic temperature conditions of the area in which the ATEC facility is to operate will vary according to geographical and topographical locations. The ATEC facility will be housed, or sheltered, indoors for operation and, for the purpose of establishing a mean, a temperate climatic zone will be used as a reference. The ambient temperature for operation of the ATEC facility will normally range between 70^{o}F (21^{o}C) and 80^{o}F (26.5^{o}C) depending on area and operator comfort provisions. In temperate and tropical zones which will have high climatic temperatures in excess of the requirement for operational ambient temperature, air conditioning will be required. In temperate and arctic zones, or in the case of high elevation, which will have low climate temperatures, heating will be required. The amount of air conditiong and/or heating required for a particular ATEC facility

will be determined on a per site basis. Equipment design for the ATEC facility must take the operational ambient temperature into account and also make allowance for operation outside the normal range. Commercial, off-the-shelf equipment is usually specified for operation over such a range as 32°F (0°C) to 104°F (40°C) or to 122°F (50°C). The individual equipment specifications will specify the operating ambient temperature range requirement based on equipment design and function in the ATEC system.

The requirement for relative humidity in equipment and operating spaces has usually been set at 50 percent with an allowable variation of ± 20 percent for personnel comfort and equipment operation. In areas of high temperature and humidity, the air conditioning system provides removal of moisture from the air and thus lowers the relative humidity to an acceptable level. In areas of low humidity and/or low temperature requiring heating of the operational spaces, humidifier units will be required to bring the relative humidity up to an acceptable level. Commercial, off-the-shelf equipment is usually specified for operation over a range such as 10 percent R.H. to 90 percent R.H. The individual equipment specifications will specify the operating range of relative humidity based on equipment design and functions in the ATEC system.

The requirement for operation at various altitudes involves the atmospheric pressure at these elevations and the operating range for electronic equipment is normally set from 30 in. Hg (762 mm Hg) at sea level to 20.3 in. Hg (515 mm Hg) at 10,000 feet. This range of altitude is sufficient to include any elevation at which an ATEC facility might be located. The individual equipment specifications will specify the operating range of altitude based on equipment design and function in the ATEC system.

The equipment to be provided for the ATEC facility must also consider operation in a salt or corrosive atmosphere and an environment which may have dust particles in the air. Also to be considered is protection against fungus. The problems of operating in a corrosive atmosphere or dusty environment are acute when equipment functions or design depend upon metal-to-metal contacts which may corrode or become dirt covered so as to prevent or lessen operational capability. The equipment must not be built with materials that may contain fungus nutrients or, in case no other material will suffice, be provided with protective coating on exposed surfaces of those materials. The individual equipment specifications will specify the requirements for these service conditions based on equipment design and function in the ATEC system.

[illegible] Electromagnetic Interference/Compatibility

The requirements for protection against Electromagnetic Interference (EMI) and for Electromagnetic Compatibility (EMC) in the ATEC facility are to be considered on a system basis and also on an individual equipment basis. All electronic [illegible], electrical maintenance tools, or other el[illegible]cal devices

will be required to have minimal interference generating capability to be compatible with the ATEC facility. Electrical devices found to have detrimental effects upon ATEC equipment will be required to be replaced with noninterfering devices; or will be shielded or filtered, or both, to bring interferring signals down to an acceptable level. The ATEC equipment must also be designed so as not to be susceptible to normal radiating signals from other equipment or sources in the ATEC facility. Electromagnetic compatibility requires that equipment, which is connected to make up a system, neither generate nor be susceptible to interferring signal levels. The equipment must operate satisfactorily, not only independently, but also in conjunction with other equipment which may be located nearby. The individual equipment specifications will specify the EMI/EMC requirements based on equipment design and function in the ATEC system.

3.7.4 Training and Personnel

The contractual requirement for training and personnel, in regard to the ATEC facility, is that any specific training requirements for the tech controllers and maintenance personnel will be identified. The ATEC facility, because of the installation of complex equipment and consoles, and new operational concepts, will require instruction that is commensurate with the skill levels, experience and ability to assimilate training that characterizes the type of operational and maintenance personnel presently assigned to tech control facilities. Section XVII, Human Factors, in Volume II has analyzed the capabilities required of tech control and maintenance personnel for the ATEC facility. The following paragraphs provide a discussion of specific training and personnel requirements.

The specific training requirements for tech control personnel will concern the functions of the ATEC system, understanding of electronic data processing as applied in the ATEC system, and a thorough knowledge of console operation and functions as provided for ATEC. The ATEC facility will engender new procedures stemming from the enhanced capabilities of monitoring and sensoring. The central control personnel must be able to make changes and update the computer data base for both record and report generation. The status and monitor personnel for system, link, circuit and equipment must be able to analyze display information and make decisions based on apriori or near-real-time data. Finally, and perhaps most important, the tech controllers must be made to understand that the ATEC system is semi-automated, not an automatic, system and that the facilities provided are to enhance the tech controller's capabilities and are not to replace them. The man-machine interface is still as important as it ever was, with the tech controller as the deciding link in the feedback loop function of the ATEC system.

The following is a listing of nominal training requirements for operator personnel at ATEC facilities.

POSITION TITLE	FORMAL TRAINING	OJT
Shift Supervisor	100 hours	3 months
Central Control	80 hours	3 months
Status Monitoring	60 hours	1 month
Quality Control	80 hours	1 month
Tech Controller	60 hours	1 month

The specific training requirements for maintenance personnel will involve the functional and performance characteristics of the ATEC system and of the equipment provided for the system. The major items requiring instruction in preventive maintenance, and in localization, isolation and repair of failures are: (a) processor and peripheral equipment, (b) display and control console equipment, (c) switching matrices and ancillary equipment, (d) sensor and telemetry equipment, and (e) specialized test equipment. Each of these may be considered a separate area for instruction or specialization, however, all will require a basic knowledge of solid-state and switching equipment troubleshooting methods.

The following is a listing of nominal training requirements for maintenance personnel at ATEC facilities.

DESCRIPTION	FORMAL TRAINING	OJT
Electronic Digital Data Processing Repairman	200 hours	2 months
Microwave and Communications Relay Center Repairman	40 hours	2 weeks
Wire and Inside Plant Cable Repairman	20 hours	2 weeks

The skill level requirements, for the operational and maintenance personnel in the ATEC, will be commensurate with those normally assigned to the present TCF's. The present Air Force TCF's utilize operational personnel in the AFSC (Air Force Specialty Code) 307X0 career field (the "X" designating the skill level). The skill level of these assigned tech controllers usually varies from 3-level for airmen, to 5-level for sergeants and staff sergeants to 7-level for tech and master sergeants, and to 9-level for senior and chief master sergeants. The quantities of each skill level to be assigned to an ATEC facility will obviously depend upon the operational requirements and size of the station. The status monitoring and quality control console positions will nominally require 5-level operating personnel but 3-level personnel, with appropriate OJT (On-The-Job-Training), will be able to operate the consoles and perform the required functions (with supervision for unusual situations). The central control console position will nominally require a 7-level tech controller but 5-level personnel, again after appropriate OJT, will be able to operate the consoles and perform the required functions. The 9-level personnel will continue to perform the tech control administrative and supervisory functions presently assigned; although these personnel will also need to know facets of each operation and function in the ATEC.

The maintenance personnel presently assigned to Air Force TCF's are usually in the 304X0 (Microwave and Communication Relay Center Repairman) and 362X0 (wire and Inside Plant Cable Repairman) career fields. To these, for ATEC, will be added the AFSC 305X1 (Electronic Digital Data Processing Repairman). The skill level of these maintenance personnel will vary from 3 to 5 to 7 to 9, depending on the quantities and types of equipment to be maintained. Normal maintenance functions will require 5-level personnel but 3-level personnel, with adequate OJT, will be able to perform maintenance and repair (with supervision for unusual situations). The 7 or 9-level personnel, if assigned, will continue to perform the maintenance administrative and supervisory functions presently assigned, although they will also be required to know the theory and operation of the ATEC system/facility and equipments.

The following is a typical listing of nominal skill level manning requirements at Air Force ATEC facilities.

		ATEC FACILITY SIZE		
POSITION/DESCRIPTION	AFSC	SMALL	MEDIUM	LARGE
Shift Supervisor	30770	1	1	1
Central Control	30770	1	1	1
Status Monitoring	30750	1	2	3

(Typical Listing Continued)

POSITION/DESCRIPTION	AFSC	ATEC FACILITY SIZE SMALL	MEDIUM	LARGE
Quality Control	30750	1	1	2
Tech Controller	30730	1	2	3
Electronic Digital	30571	0	0	1
Data Processing	30551	1	1	1
Repairman	30531	0	1	1
	Subtotals	6	9	13
Total Personnel (X4.2 Shifts)		25	38	55

3.7.5 Quality Assurance

The recognized principles of Quality Assurance will be a requirement in support of ATEC facility implementation. In accordance with provisions of AFSCM/AFLCM-375-1, "Configuration Management During Definition and Acquisition Phases", Exhibits I and II, requirements for formal tests and/or verifications will be included in Section 4 of the system specification and individual equipment (CEI) specifications.

The requirements for QA in the system specification will include Category I and Category II testing of system performance, design characteristics and operability.

Category I tests/verifications will include both in-plant and integrated system testing. An analysis of Category I test requirements indicates that Engineering Test and Evaluation in support of design and development activity will not be required. Formal Qualification Testing will be limited to the contract end item level, with the exception of components designated as Engineering Critical Components, which will be individually qualified. Demonstration that the required system reliability has been achieved will be accomplished by data analysis. The data item "ATEC Reliability and Maintainability Analysis", will be used to establish the format and requirements of the data analysis.

Category II (or equivalent) system testing will be defined for an integrated test of the complete ATEC system in the final environment. Category II tests will be specified in accordance with approved test plans developed to demonstrate compliance with the requirements of Section 3 of the system specification.

The requirements for QA in the Part I CEI detail equipment specifications will include verification of performance, design and construction. Verification will be accomplished by inspections, demonstrations, or tests of the requirements of Section 3 of the CEI specifications in a Category I test.

The Category I test will include all testing of the CEI required to satisfy the requirements of the specification. Engineering Test and Evaluation to verify interface requirements in a subsystem configuration will be included in a Subsystem Test Plan. Preliminary Qualification Tests will not normally be required unless specified by the procuring activity. Formal Qualification Tests will include inspections, analysis, demonstrations and tests necessary to verify requirements of Section 3. Reliability Tests and Analysis will be performed to verify reliability requirements in Section 3. If any of the components are found too critical, then Engineering Critical Component Qualification Testing will be specified for that item. Category II tests will not normally be required unless requirements contained in Section 3 cannot be verified until the CEI is assembled into or used with other system equipment. Such requirements, however, will be incorporated only upon specific approval of the procuring activity.

3.7.6 Test Equipment

The test equipment (Maintenance Ground Equipment) requirements for the ATEC facility will encompass those devices required to restore the system, subsystems or equipment to operating condition. The test equipment recommended for use by maintenance personnel has been delineated in Volume II, Section XXI, Maintenance Test Equipment. Provision of these items will be subject to approval by the procuring activity.

SECTION V

ATEC COST-EFFECTIVENESS ANALYSIS

1. INTRODUCTION

An analysis of the relative utility of any system or process must include an assessment of the benefits derived from its use versus the resources expended for its implementation. In general, since total resources of the nation and the Department of Defense are limited, it is mandatory that the Government invest in those systems that achieve the highest level of effectiveness or "payoff". By selecting those systems possessing high relative payoffs, the total resources of the Government may be conserved and maximum effectiveness achieved for a given budget.

The ATEC cost-effectiveness program was developed with the same basic goal: to maximize the efficiency of a given investment in an ATEC system. To achieve this goal, a coordinated program to assess equipment, subsystems, systems, functions, and station types was undertaken. Each decision involving selection of equipment items, measurement functions, and subsystems was accomplished on a cost-effectiveness basis.

2. PURPOSE AND SCOPE

The ATEC cost-effectiveness program was structured to provide for the development of methodology adequate to assess the benefits relative to cost of implementing alternative ATEC systems. Specifically, the program was designed to accomplish an optimal ATEC based on maximizing the return on invested capital.

3. METHODOLOGY

3.1 Cost Model - By ATEC Function and Site

To adequately assess the most effective ATEC functions and facility size, it is first necessary to calculate costs for these functions and differing sized sites/facilities. The methodology employed in this costing operation is quite straightforward. The equipments and systems required were listed and the costs developed in the equipment and subsystem costing phases are merely summed and added to the cost of unique manpower, training, and replacement spare requirements. The total cost by site and function is compared with the discounted cost savings due to manpower economies and increased circuit availability. The return on invested capital can then be calculated on an annual basis.

3.2 Measurement of Effectiveness

The components of system cost have been expressed in dollar terms. To compare the cost and "revenue" components during implementation of an ATEC system, it is necessary to obtain an economic expression the the benefits of ATEC. To accomplish this, the economic benefits from ATEC were derived from the savings in manpower and circuit availability due to implementation of the system. The savings in man hours were equated to dollar terms by assuming a wage and benefit rate of $7.80 per hour. The dollar savings in circuit availability were obtained by multiplying the time saved (per circuit), due to employing ATEC, times a rate of $8.40 per circuit hour. This rate was derived from the DOD Rule-of-Thumb Pricing Guide for Military C-E System

The essence of cost-effectiveness analysis is to compare the cost of obtaining a capability versus assessing its benefits. This analysis has expressed both cost and effectiveness in dollar terms. To assess the "payoff" from ATEC, the return on invested capital was calculated by site and function. The results of this analysis, which are presented in paragraph 4 of this section, indicate some most significant implications for policy toward ATEC.

The ATEC system was divided into functions in order to facilitate the measurement of system effectiveness as well as effectiveness of the individual functions. The following represents a list of the functions:

Function 1 -

- Fault Detection and Isolation

Function 2 -

- Equipment/Link Monitoring

Function 3 -

- Automated Patching

Function 4 -

- Reporting

Function 5 -

- Circuit Qualification and Testing

Function 6 -

- Remote Site Equipment/Link Monitoring

Appendix I, Volume I, of this report contains the details of the cost-effectiveness calculations. The following subparagraphs summarize the methodology employed in the detailed calculations.

3.2.1 Effectiveness of Functions

3.2.1.1 Function 1 - Fault Detection and Isolation

The results of the calculations show that the largest savings are obtained by implementing the fault detection function. This saving is largely due to a recovery of indeterminate outage time. This may be defined as the time from the occurrence of the failure to the time it is reported to or observed by tech control. For DC circuits in the present manual system, this outage time was estimated to be approximately 11 minutes and consists mainly of the time it takes an operator to become aware of the fact that a failure has occurred. This delay is caused by the lack of an effective means for detecting a fault on an operating circuit. For VF circuits the indeterminate outage time was estimated to be 63 minutes. The rationale employed here was that voice circuits are not used 100 percent of the time and for some circuits this idle period could extend up to a period of several hours. The dollar savings in this area is $21.06 per year for each DC circuit and $798.58 per year for each VF circuit.

The fault isolation operation is in two parts; first is a determination of whether the failure is within the facility or external to the facility and second, if it is within the facility, a determination of what equipment has failed. The savings for the first fault isolation function is $40.34 per year for each DC circuit and $125.30 per year for each VF circuit. The savings for the second fault isolation function is $11.87 per year for each DC circuit and $34.32 per year for each VF circuit.

The total circuit outage cost savings for Function 1 is $113.27 for each DC circuit and $958.20 for each VF circuit.

3.2.1.2 Function 2 - Equipment/Link Monitoring

The savings due to Equipment/Link Monitoring is again due to indeterminate outage time. However, savings are not as great as in Function 1. This can be observed by examining the distribution of failures as they are observed at one node. Ninety-two percent of the failures occur external to the node, while only eight percent occur within the mode. Since Function 2 involves monitoring equipment within the node, it can only be slightly more than 1/10 as effective as Function 1 because of the failure distribution. The savings attributable to Function 2 are $0.44 per year for each DC circuit and $8.29 per year for each VF circuit.

3.2.1.3 Function 3 - Automated Patching

The savings that can be obtained from automated patching are in two areas, a reduction in outage time and a savings in the manpower required to accomplish the patch. However, these savings are only available when patching is necessary at the ATEC facility in restoring the failed circuit to service. An analysis

of the information available on Fuchu Air Station yielded an average circuit of 1000 miles in length with 9 nodes. By assuming that the ATEC was the middle node and analyzing all of the possible combinations of patching, the ATEC was involved in patching 1/5 of the time for failures external to the ATEC. The total savings for Function 3 are $7.78 per year for each DC circuit and $17.02 per year for each VF circuit.

3.2.1.4 Function 4 - Reporting

The savings obtainable by automating the reporting function occur only in the reduction of the manpower required to make the report. Outage time savings are unattainable since the report is normally constructed after the necessary restorative actions have been completed. Since outage time savings are not a part of the savings for Function 4, the difference in vlaue for DC circuits and VF circuits has no effect. The savings are $20.88 per year for each circuit.

3.2.1.5 Function 5 - Circuit Qualification Testing

There are three areas where savings can be obtained by automating this function: testing as required as part of the restoration; testing as required as a quality control function; and the reduced outage as a function of increased effectiveness of the quality control function. The summation of the effects of all of these taken together is a savings of $76.51 for each DC circuit, and $320.73 for each VF circuit.

3.2.1.6 Function 6 - Remote Site Equipment/Link Monitoring

The addition of remote site equipment/link monitoring results in some savings that have been obtained at the main ATEC facility. The interaction is in the area of savings of the indeterminate outage time; that is, the main facility also observes the failure and would react to notify the remote site. With the remote site monitoring its own equipment, it would take direct action to correct the failure. With the addition of remote site monitoring, savings are obtained because the failures that occur at the remote site are transferred from the category of notifying someone else that there is a failure to the category of taking direct action and immediately resolving the problem. The outage time savings for the direct action type of failures was assumed to be the average outage time calculated from the Fuchu failure reports less the time it takes the ATEC facility to restore the circuit to service. The outage time savings for the notify action type of failure was assumed to be the reduction in reaction time due to the implementation of ATEC and only for the period of time that the ATEC facility was involved with the failure. The difference between the savings from direct action and notify action type of failures is a large percentage saving in the average outage time. The net savings for this function will be $12.12 per year per DC circuit and $72.64 per year per VF circuit.

3.3 Effectiveness of Sites

Three model size sites were established by an evaluation of 72 DCS stations in order to measure the variation in effectiveness due to the size of an ATEC facility.

3.3.1 Small Site

The model small site was calculated to contain 60 channels composed of 40 VF channels and 20 DC channels, of which 38 VF channels were for VF circuits and two were for the tone side of the DC multiplex. There were no remote sites associated with the small facility. Following is a tabulation of the yearly dollar savings that can be expected for each function and the total for this ATEC facility.

Annual Dollar Savings - Small Site

Function	Savings
1	$40,593
2	340
3	836
4	1,253
5	14,359
6	---
Facility	$57,381

3.3.2 Medium Site

A medium site was calculated to contain 420 channels composed of 260 VF channels and 160 DC channels, of which 250 VF channels were for VF circuits and 10 were for the tone side of the DC multiplex. There was assumed to be an HF transmitter and receiver site associated with the medium facility. Following is a tabulation of the yearly dollar savings that can be expected for each function and the total for this ATEC facility.

Annual Dollar Savings - Medium Site

Function	Savings
1	$267,255
2	2,226
3	5,670
4	8,770
5	95,631
6	2,380
Facility	$381,932

3.3.3 Large Site

A large site was calculated to contain 1100 channels composed of 560 VF channels and 540 DC channels, of which 533 VF channels were for VF circuits and 27 were for the tone side of the DC multiplex. These were assumed to be an HF transmitter and receiver site associated with the large facility. Following is a tabulation of the yearly dollar savings that can be expected for each function and the total for the ATEC system.

Annual Dollar Savings - Large Site

Function	Savings
1	$597,758
2	4,880
3	12,732
4	22,968
5	220,924
6	3,093
Facility	$863,355

4. RESULTS

4.1 ATEC Equipment and M&O Costs

The results of the analysis of the 72 DCS stations yielded channel capacities for the three size statistical models Assumptions were made relative to the numbers of links, the type of links, the quantity of connected users and the quantity of through circuits. For each of the three model sites, an equipment summary was developed. The equipments were segregated and listed in the same functional groupings that were used for the measurement of the ATEC system effectiveness. The equipments that required development were analyzed and an estimate of the one time development costs and recurring procurement costs were made. Catalog prices were used for off-the-shelf equipments. In order to develop a statistical spread of the one time costs an assumption was made that the procurement of ATEC for the overall DCS would be for 8 large sites, 25 medium sites and 17 small sites. Additionally, partial implementation of some sites will more than affect any inaccuracies incurred in using this distribution. The accrued costs for each function and for one of each of the three size ATEC facilities were gathered together and are presented in the cost rows of Table IV. No costs were included for ATEC maintenance.

Improved efficiencies in DCS station maintenance will more than affect additional burdens imposed on maintenance by the addition of the ATEC facility. This is exemplified by: (a) earlier detection of faults prior to catastrophic failure, (b) assistance to maintenance in fault location through the fault isolation function, (c) allowance of more effective deployment of maintenance personnel through greater effectiveness of the quality assurance function.

VFCT Tone Channels	11	15%	50%
Average Indeterminate Outage Time VF - 63.7 Min.	--	--	--

For VF circuits the minimum response time was estimated assuming the voice circuit was in use and the maximum response time was estimated assuming the whole circuit was idle and some time would elapse before it was used or [illegible]. An estimate was then made of the density of the circuit types and also of the probability that a failure would occur on that circuit type. From Table V, the average indeterminate outage time for DC circuits is 11.0 minutes. The average reaction time for the ATEC system on DC circuits is one-half of the monitor scan cycle time of two minutes. Therefore, the average indeterminate outage time savings for DC circuits is [illegible] minutes ([illegible]). Again, from Table V, the average indeterminate outage time for VF circuits is 63.7 minutes. The average reaction time for the ATEC system on VF circuits is one-half of the scan cycle time of one minute. Therefore, the average [illegible]

[illegible] the failure by function 4. The three corrective actions [illegible] tion, equipment substitution or equipment repair which make use of function 6, "Automated Patching".

The calculations for direct action outage time savings for node [illegible] failures

DAS = T - ΔA - AIND

T = 96 minutes - reference Table IV

ΔA = AIND + [illegible]

where FT = function

ΔA = Minimum reaction time of ATEC system

[illegible]

- Availability of maintenance man performing other duties

  Minimum time = 1
  Maximum time = 15
  Average time = [illegible]

- Investigate equipment problems

  Minimum time = 2
  Maximum time = 15
  Average time = [illegible]

- Obtain spare module for repair

  Minimum time = 4
  Maximum time = [illegible]
  Average time = [illegible]

AIND A1A

FU1B is the most current diagnosis

Reaction times — Manual = [illegible], ATEC = [illegible]

Average = [illegible]

FU1C is the intra-node diagnosis

Reaction times — Manual = [illegible], ATEC = [illegible]

Average = [illegible]

[illegible]

the AIND portion equals

AIND = [illegible]

inserting in the DAS formula DAS = T - [illegible]

DAS = 96 - [illegible]

A user terminal failure is detected by FU1A, followed by an individual diagnosis to determine if the failure is internal or external to the ATEC by FU1B. FU1C detects the failure on the circuit serving the [illegible]. [illegible] detects the fault in the circuit between the user terminals. Both [illegible] require coordination with the user terminals. The two corrective actions are either equipment substitution or equipment repair. This is followed by a qualification test before the circuit is restored to service.

In a simil[illegible] distributed o[illegible] perform the f[illegible]

Function [illegible]
FU1A
FU1B
FU1[illegible]

User Terminal Failures

Notify Action (8.61% failure distribution from Table III)

Outage savings (formula 6)

$$NAS = 8.61\% \left[(AIND)\ A1A + 2.8A1B + 0.2A3 + 0.14A5 \right]$$

$$\boxed{0.09\ (AIND)\ A1A + 0.24A1B + 0.02A3 + 0.01A5}$$

(User Terminal - Notify - Outage)

Manpower Savings (User Terminal - Notify Action)

In the manual system when a failure is reported a diagnostic action (FU1B) will take place to determine if the failure is internal or external. In the case being discussed the failure is external resulting in coordination with the next node. Patching and testing would not be involved in this case. A report would be generated (FU4).

ATEC will save all of the manpower for the diagnostic (FU1B) and part of the reporting (FU4).

In the manual system when a failure is reported a diagnostic action (FU1B) will take place to determine if the failure is internal or external. In the case being discussed, the failure is external and immediately identifies the user terminal as the source of the failure. The failure would then be reported (FU4).

ATEC can save all of the manpower for the diagnostic (FU1B) and some of the manpower for the report (FU4).

(diagnostic)	Manual time FU1B	= [illegible]
(reporting)	Manual time FU4	= 1.2
	ATEC time FU4	= [illegible]
	Savings FU4	= [illegible]

$$1.74\%\ ([illegible]A1B + [illegible]A4) = \boxed{[illegible]A1B + [illegible]A4}$$

(User Terminal - Direct - Manpower)

Outside DCS Failures

Notify Action ([illegible]% failure distribution from Table III)

[illegible]

(diagnostic)	Manual time [illegible]	= [illegible]
(patching) [illegible]	Manual time [illegible]	= [illegible]
	ATEC time [illegible]	= [illegible]
	Savings [illegible]	= [illegible]
(testing) [illegible]	Manual time [illegible]	= [illegible]
	ATEC time [illegible]	= [illegible]
	Savings [illegible]	= [illegible]
(reporting)	Manual time [illegible]	= [illegible]
	ATEC time [illegible]	= [illegible]
	Saving [illegible]	= [illegible]

[illegible]

$$\boxed{[illegible]}$$

(Outside DCS - Notify - Manpower)

When remote site monitoring is implemented, it is closely associated with the ATEC monitoring. This means there is interaction between the two monitoring subsystems insofar as savings are concerned. The main ATEC node failures that occur at the remote site is in the notify action category. Implementation of remote site monitoring brings these failures within the direction action category. The additional savings that can be obtained from remote site monitoring is the differ[illegible]

RSS = [illegible] A5 - ([illegible]) A5

RSS = [illegible] A5

The savings available to the remote site monitoring system are node failures in the direct action category and are a savings in outage time only.

[illegible]% failure distribution from Table III

RSS = [illegible]% ([illegible] A5)

$\boxed{[illegible]\ A5}$

(Node - Notify - Outage)

Function 5, "Circuit Qualification and Testing" will afford savings in manpower in performing the quality monitoring function in addition to the testing associated with failures. An analysis of quality control schedule in DCAC [illegible], Volume I yielded the following results

Manual System

[illegible] minutes per year per DC circuit [illegible] testing plus [illegible] minutes per year test equipment set up time

Manual	[illegible] VF + [illegible]
ATEC	[illegible] VF + [illegible]
Savings/year	[illegible] VF + [illegible]

Formula 7

[illegible] DC + [illegible] VF + [illegible] note: this is savings in minutes per year

(other sources - [illegible])

Function 5, "Circuit Qualification and Testing" will also result in a reduction in the failure time. This reduction was estimated to be [illegible]%, however, in keeping with the conservative estimates so far used in the calculations, a reduction of [illegible]% will be used.

Savings have already been calculated for the failures that occur at a station. The additional savings is a reduction of the ATEC time plus the outage time that could not be saved for the failures that will be eliminated.

The direct action savings will be the total outage time less the savings already calculated.

Total outage time	= T - AIND
Calculated savings	= DAS
FU5 savings	= T - AIND - DAS

outage savings

T - AIND - [illegible] = [illegible]

[illegible]% X [illegible] = [illegible] A5 outage time

manpower savings

[illegible] A1B + [illegible] A3 + [illegible] A4 + [illegible] A5 = [illegible]

[illegible]% X [illegible] = [illegible] A5 manpower

DIRECT ([illegible]%)

outage savings

T - AIND - DAS = [illegible]

[illegible]% X [illegible] = [illegible] A5 outage time

manpower savings

[illegible] A1B + [illegible] A1C + [illegible] A3 + [illegible] A4 + [illegible] A5 = [illegible]

[illegible]% X [illegible] = [illegible] A5 manpower

Table IV Comparison of ATEC Cost Effectiveness by Site Size and Function

STATION		FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5	FUNCTION 6	TOTAL SYSTEM
SMALL 60 Channels 20 DC Circuits 40 VF Circuits No Remote Sites	Savings	$40,593	$340	$836	$1,253	$14,359	-	$57,381
	Cost	$361,573	$27,639	$235,823	$42,500	$306,056	-	$973,591
	Pay-Off Period	17.4 Y	∞	∞	∞	∞	-	∞
MEDIUM 420 Channels 160 DC Circuits 260 VF Circuits 2 Remote Sites 24 Channels Ea.	Savings	$267,255	$2,226	$5,670	$8,770	$95,631	$2,380	$381,932
	Cost	$568,723	$55,998	$537,750	$42,500	$436,556	$125,198	$1,766,725
	Pay-Off Period	2.3 Y	∞	∞	6.1 Y	5.6 Y	∞	5.7 Y
LARGE 1100 Channels 540 DC Circuits 560 VF Circuits 2 Remote Sites 36 Channels Ea.	Savings	$557,758	$4,880	$13,732	$22,968	$220,924	$3,093	$863,355
	Cost	$933,023	$88,812	$1,330,875	$60,750	$573,806	$145,358	$3,132,624
	Pay-Off Period	1.6 Y	∞	∞	2.9 Y	2.8 Y	∞	4.2 Y

4.2 Cost-Effectiveness Summary

Table IV presents a comparison of the cost-effectiveness for the three size sites and for each of the functions of the ATEC system. The payoff period has been calculated employing a discount rate of 10 percent. As indicated in the tables, some functions and site sizes have an infinite payoff. This is due to the payoff being of lesser value than the discount rate on an annual basis. It would appear that Functions 2, 3, 6 are of marginal productivity and cannot be recommended on a cost-effective basis.

This cost-effectiveness data has been developed in part from information obtained on the Technical Control Activities at the Fuchu station. This information provides a view of the DCS which indicates 97.8% efficiency. If in other geographical areas this efficiency is different, the ATEC payoff periods change quite dramatically as shown in Figure 19.

5. CONCLUSIONS

The net cash flow analysis presented in the preceding paragraphs exhibits some rather startling differences in the return on invested capital. Of the six basic ATEC functions, fault detection and isolation testing and reporting appear to have a significant payoff in economic terms. The other basic functions - automated patching, remote site monitoring, and equipment/link monitoring have little or no advantage from a cost-benefit standpoint. The payoff period for these items approaches infinity. Since the net return on invested capital is less than the assumed discount rate of 10 percent, the net return on these functions is, in fact, negative. On the basis of this analysis, it would appear that the fault isolation, reporting and testing functions should be implemented as a first priority to maximize the immediate payoff. The implementation of other functions could then be considered if justifiable on a more qualitative basis.

The cost-benefit analysis also considered and compared the degree of payoff by size of the ATEC sites. The percentage payoff increases with site size to about 18 percent for the large ATEC facility. The payoff period for the large site is 4.2 years. The return from the medium sized ATEC facility is about 13 percent per year resulting in a payoff period on a discounted basis of 5.7 years. The small ATEC facility never achieves a net payoff and would therefore not be recommended as a promising use of economic resources. However, this does not preclude the selective implementation of certain key ATEC facility techniques in smaller facilities.

Combining these most significant results yields the conclusion that an optimal strategy would be to invest in fault isolation testing and reporting at large and medium ATEC sites. The payoff period in such a strategy is 1.9 and 3.1 years, respectively. The payoff from implementing these functions at the small sites is quite low and is not recommended. Again, the other ATEC functions at any size facility do not appear to warrant implementation from a cost-effectiveness standpoint.

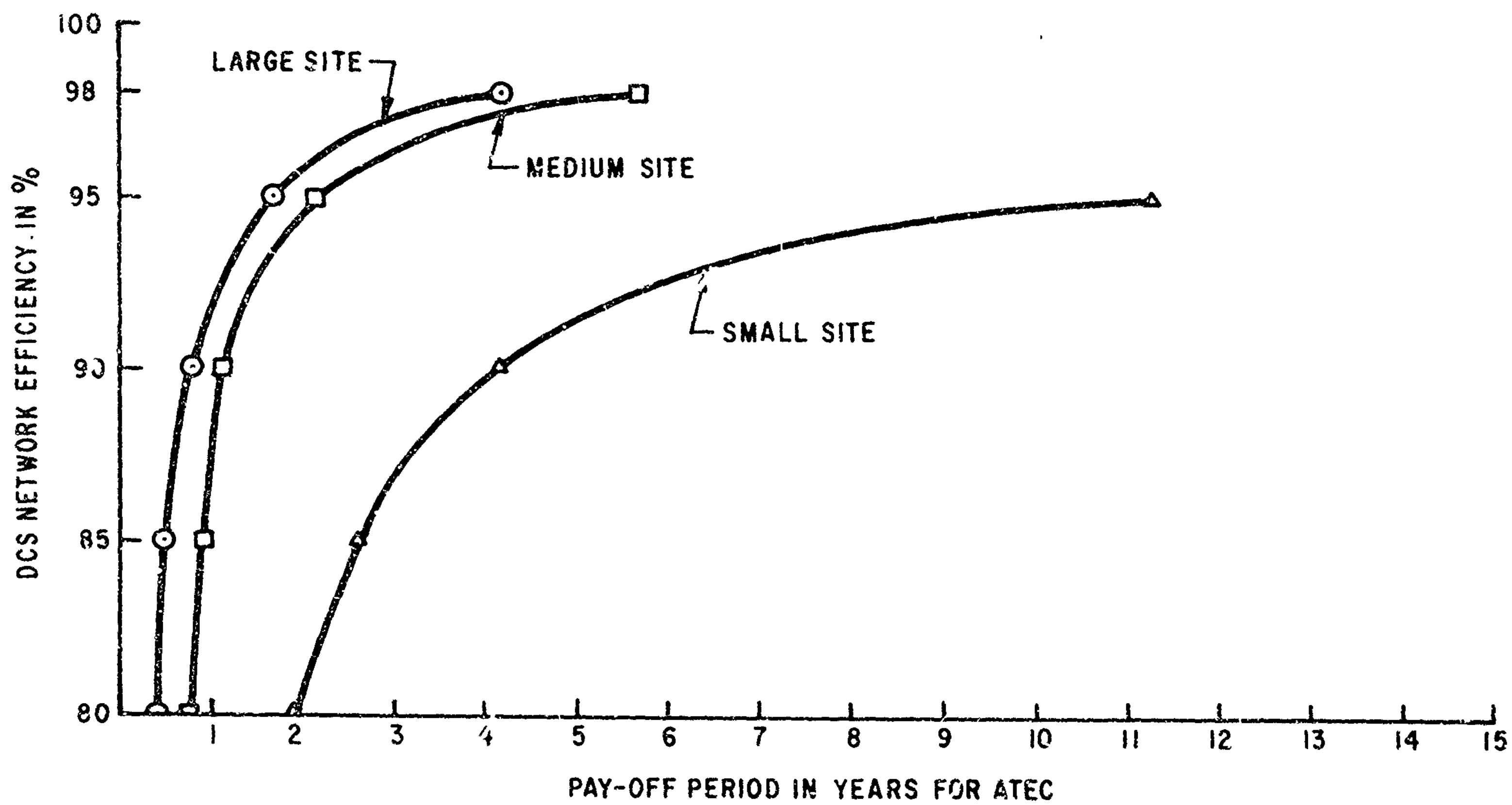


FIGURE 19 ATEC PAY-OFF PERIOD AS A FUNCTION OF DCS EFFICIENCY

The basic technique and data used to develop the various alternative strategies are presented in Appendix I, permitting the reader to calculate simply any alternative strategy that might be of interest.

This analysis did not consider a detailed time-phase implementation plan on a worldwide basis. Such an analysis is a major undertaking and must consider a host of different implementation strategies in great detail over a five to ten year period. Implementation planning of this type is necessary to achieve true cost-effectiveness in the final implemented system.

Some comments can be made, however, concerning implementation strategy. Briefly, the highest payoff occurs from implementing the fault isolation function at large sites. Thus, this function should be implemented first. As more sites are implemented, the incremental payoff from adding each site will not be as high as the preceding one since they will tend to interact. This is a well known economic principle known as eventually decreasing marginal productivity of capital. To alleviate this problem in ATEC, it would appear to be a wise strategy to separate the implemented ATEC sites very widely so as to minimize interaction and maximize the potential payoff.

It is anticipated that certain TCF's within the DCS will be prime candidates for total implementation of all ATEC capabilities. These TCF's will undoubtedly be those at major nodal points within the DCS and as such will probably also be DCS reporting stations. It is conceivable that the implementation of ATEC could be restricted to a small number (perhaps 15 to 30) of such selected sites, and that marked benefits could be derived from such a limited implementation; particularly as a result of the circuit monitoring concepts of the recommended ATEC facility design. If such a limited implementation is undertaken, the result will be a mixture of totally automated TCF's and of totally manual TCF's. This mixture of the old and the new is certain to contribute numerous impediments to achieving the primary objectives of ATEC. For example, the ATEC facility, having detected a fault and having initiated a request for a quality check at a manual TCF, must standby until the results of manual monitoring techniques (including the inherent inaccuracies of human accomplishment and interpretation) are reported. Hence, while a fault was detected rapidly, its verification and isolation might require an incompatibly longer time.

The objective here is to identify phased implementation approaches of the functional elements which could provide the greatest benefit for any given expenditure of time and money.

The total recommended ATEC facility configuration is separable into a number of functional modules. These may be identified as follows:

a. Circuit Monitoring

b. Link/Equipment Monitoring

c. Improved Manual Patching

d. Test Busses and Quality Control Console

e. Fault Isolation

f. Data Base

g. Remote Site Monitoring

h. Reporting and Record Keeping

i. Automated Patching

Each of these functional modules benefits (to a greater or lesser degree) from the presence of a certain amount of data processing, data analysis, display and control, operator evaluation, and other similar support elements. However, certain of the functional modules, namely, (1) improved manual patching, (2) test busses and quality control, and (3) the DC portion of the circuit monitoring, can be implemented individually and independently without the presence of the above support elements. Also, certain other functional modules which require processing and its related elements can be implemented at a given TCF and share the required processing located at a nearby TCF which has been more fully automated. Such functional modules include (1) circuit monitoring, (2) link/equipment monitoring, (3) fault isolation, and even limited data base and reporting and record keeping capabilities. The important factor here is that communications channels required for access to the remotely located processor must not be permitted to exceed the cost of a processor and related hardware; and, also, the total cost of such communications channels must not exceed the benefits which result from such use. Section XII (of this report), Telemetry Analysis, provides a detailed investigation of approaches to obtaining such channels, e.g., speech-plus, time sharing and others.

Essentially, there are three basic methods of implementing ATEC on a world-wide basis: (1) total implementation (all functional modules) of a selected number of TCF's, with additional TCF's implemented as a function of time; (2) partial implementation (selected functional modules) of a larger number of TCF's, with additional TCF's implemented as a function of time; and (3) total implementation (all functional modules), but only for selected circuits at a large number of TCF's. Of course, there

are variations of each of the above basic methods, as well as hybrid approaches (combining elements of each of the above basic methods). The first method results in implementation of the fewest number of stations. The remaining two methods allow for implementation of a larger number of stations, with the second method probably resulting in the largest number. For the third method, all of the basic hardware elements are required and hence the major part of the total cost is incurred (fewer dollars are needed to expand a functional module once its basic elements are obtained).

On the basis of all facts known to date, it is recommended that an implementation approach be adopted which would result in the total implementation of all ATEC functions at selected major TCF's and partial implementation (selected functional modules) at other key TCF's. The totally implemented TCF's would be those having particularly strategic positions in the DCS and/or having a large technical control requirement. These partially implemented TCF's may have their own processor and related peripheral equipment or may share such facilities at the associated fully implemented TCF: this determination must be made in the form of a cost tradeoff (processor and peripheral vs. communications channels) on a per station basis. The centrally located fully implemented TCF would exercise operational control, including coordination and reporting, for the assigned partially implemented TCF's.

The actual time phased implementation actions required to achieve the final or eventual world-wide ATEC configuration are expected to be a function of available funding. Therefore, it is recommended that a time phased sequence of ATEC implementation be adopted for all stations to be implemented (fully implemented or partially implemented). This sequence should be related to the functional modules as listed earlier. The particular sequence may vary depending upon the mission and needs of the particular TCF and can be terminated at any point in the sequence. However, the following sequence is expected to be generally applicable.

- Circuit monitoring - considered most valuable; includes both user drop and baseband VF channel selectors, associated VF channel analyzers, and VF channel scanner; requires processor capability, but can share a processor located remotely. Display of status can be via teletypewriter driven from remotely located processor. Digital circuits are monitored via a digital circuit analyzer requiring no external processor and employing teletypewriter for alarm and status readout. Digital circuit monitoring can be implemented at any site at any time, independent of other circuit monitoring.

- Link/equipment monitoring - considered less valuable than circuit monitoring, but a natural extension of monitoring capability; can still share remotely located processor; should not precede circuit monitoring. Implementation requires addition of equipment/link sensors, sensor scanner and A/D converter.

- Improved manual patch bays - reduces circuit noise as a result of sealed contacts; permits patch verification via cord scanning if processor is employed or when processor is added. These patch bays can be installed at any time (no processor requirement) but are required prior to implementing: (1) test busses and quality control, (2) fault isolation, and/or (3) automated patching (when justified).

- Test busses and quality control - test busses require the existence of the improved patch bays; however, they permit access to all circuits for testing and monitoring via the quality control position, and permit the addition of fault isolation. The quality control position may include a full-fledged console (CRT, associated keyboard and reference file) if a processor is located at the site; or may be abbreviated to a teletypewriter and the test equipment complex, if a processor is not available. In any case the addition of test busses and the quality control position permits circuit qualification and testing.

- Fault isolation - considered second only to circuit monitoring in value; primarily an extension of circuit monitoring in that access to intermediate circuit points is obtained; requires use of test busses, VF channel analyzer and VF channel scanner. Fault isolation could conceivably be supported by a remotely located processor, but when combined with all preceding functions, the processor information rate and hence the required intersite channel capacity might prove excessive. A cost tradeoff analysis will be required on a per site basis.

- Data base - implies many types of reference data to be employed for monitoring and testing, fault isolation, restoring and rerouting, automated patching, reporting and record keeping, as well as other functions. The data base is to be stored via a combination of magnetic tape and random access mass storage. Hence, it requires the presence of a processor. It requires, of course, tape transport and random access memory, and will probably require the expansion of processor core storage to permit optimum use of the data base.

- Remote site monitoring - refers to monitoring of remote sites which are directly under the jurisdiction of the TCF, i.e., HF transmitter and receiver sites, associated tropo and LOS terminals, LOS repeaters, and satellite earth terminals. Such monitoring is accomplished via sensors and scanners at the remote sites and is relayed to the TCF for processing. Alarms and status are returned to the remote site for presentation via teletypewriter. Remote site monitoring obviously requires a processor at the TCF.

- Reporting and record keeping - required primarily to achieve real-time reporting and record keeping, with accuracy. Requires considerable processor and associated storage capability; hence, requires presence of processor. Reporting

could, however, be handled by the centrally located fully implemented site (reporting site) since it will have status of other sites sharing its processor.

- Automated patching - a not highly cost-effective function may be required on basis other than cost. Requires existence of improved patch bays, cord scanning, processor, and control consoles. Automated patching on selected circuits (switching) is most applicable for implementation.

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

1. GENERAL CONCLUSIONS

This section presents a summary of the major conclusions and recommendations which have been drawn and developed, respectively, as a result of the study efforts carried out under the various tasks. The discussion first describes individual functional areas, then considers the ATEC system and the ATEC facility.

It is considered technically feasible to automate the following technical control functions:

a. Circuit Monitoring

b. Equipment Monitoring

c. Link Monitoring

d. Fault Isolation

e. Patching

f. Data Base

g. Reporting and Record Keeping

h. Display and Control Consoles

i. Monitoring at Remote Radio Terminals and Unmanned Repeaters.

The following functions are requirements which can enhance communications system performance and are not specifically required because of ATEC alone:

- Worldwide Clock
- Automated Line Conditioning.

2. CIRCUIT MONITORING

It is concluded that circuit monitoring will provide the major source of status information and, furthermore, is the most cost-effective of all functions amenable to automation.

It is recommended that circuit monitoring be performed at the outputs from the ATEC facility on a scanning basis. For VF circuits, monitoring should be provided on user VF receive lines and multiplex baseband VF transmit channels. Each circuit should be accessed once per minute by a VF channel analyzer which will sample for 1.2 second, measure signal level and noise, identify whether the signal sample is speech or non speech, and deliver a DC voltage in the range of 1.5 to 22.5 volts to an analog-to-digital (A/D) converter for conversion into a 6-bit digital code plus a parity bit. This digital equivalent of the measured level will be entered into a data processor for comparison against previously established Green, Amber, and Red thresholds. Amber and Red conditions will cause entry into the fault isolation function discussed below; Amber will also trigger a trend analysis operation to determine the rate of approach toward Red.

For start-stop DC circuits, monitoring will take place on user DC receive lines and VFCT transmit tone channels, measuring distortion and loss of transitions once every two minutes, on a sample of approximately one second duration. The measurement results are entered into the data processor.

For synchronous DC circuits, where the data modem is in the ATEC facility, the digital signal on the user receive line is sampled for loss of transitions.

3. EQUIPMENT MONITORING

The main benefits of equipment monitoring are derived from monitoring the performance of wideband equipment, i.e., multiplex and radio. Information on equipment affecting individual channels, such as line conditioning equipment, VF channel modems, tone keyers and converters, is more readily obtainable from circuit monitoring. Parameters to be monitored are available in many existing equipments and require the addition of standardized sensors for translating the actual parameter values into the standard range of DC voltage suitable for A/D conversion and processor entry. Equipment monitoring alone is only marginally cost-effective, but its relatively low cost warrants its inclusion as a supplement to circuit monitoring as an aid in fault isolation.

4. LINK MONITORING

Link monitoring is adequately covered by the parameters recommended for circuit/equipment monitoring.

5. FAULT ISOLATION

This function is needed to determine, first, whether the indicated circuit fault is inside or outside the ATEC facility and, second, to localize the fault within the ATEC facility or to an external site. It can correlate equipment alarms with circuit alarms and can, when necessary, perform additional measurements under processor control, supplemented by semiautomated capabilities at the status monitoring and quality control consoles. It also requires coordinated efforts with other DCS stations for external faults. This function is considered a necessary adjunct to the previously discussed monitoring functions.

Additional fault isolation capability will be provided at the status monitoring and quality control consoles. Analog and digital test equipment will be available which can access any circuit through monitor and test trunks in the circuit, primary and DC patch bays. In addition, separate trunks will be provided for the simultaneous insertion of 1000-Hz test tone on many VF circuits through the circuit patch bays and of FOX messages on many DC circuits through the DC patch bays. With these capabilities, the ATEC facility personnel will be able to assist other stations in fault isolation efforts.

6. PATCHING

It is technically feasible and effective to use a combination of manual patch bays and switching matrices for increased cost-effectiveness and reduced size and complexity of the patching facility. The matrices should have the capability for establishing simultaneous connections corresponding to the average number expected in a manual patching facility (estimated to be on the order of 10 to 15 percent of the normal-through connections), with the patch bays handling any instantaneous overflow and also providing a manual backup capability. It has been determined that the use of matrices which access all the circuits or groups appearing at the patch bays has a relatively low cost-effectiveness and does not appear to be warranted. Rather, for each site, consideration should be given to the desirability of providing matrix switching for only the most critical circuits and groups, thus reducing both size and

cost. It is also concluded that improved patch bay designs are called for to eliminate exposed contacts in signal paths, with their resultant potential for introducing contact noise, and to provide automated access to circuits for monitoring and testing purposes.

It is recommended that only four types of patch bays be used: group, circuit (equal-level), primary (cable), and DC. The VF patch bay should be eliminated. Instead, attenuator pads should be inserted between the multiplex channels and the line side of the circuit patch bays to adjust for level differences, and all line conditioning equipment (such as SF units, echo suppressors, amplifiers, pads, hybrids, signaling converters) should be located on the equipment sides of the circuit patch bays.

The improved designs for group, circuit, primary, and DC patch bays should include the following features:

a. Jacks for terminating and monitoring.

b. Sealed contact reed relays for normal through connections and for terminating the unused member of a terminating jack pair when cord patching is used.

c. Cord scanning, under processor control, to enable verification of the correctness of each cord connection or disconnection.

d. Except for the group patch, monitor and test trunks which can be accesse from the status monitoring and quality control consoles for the insertion of test signals and the extraction (by bridging or terminating) of traffic and test signals. Test trunks will also permit the insertion of 1000-Hz test tone simultaneously into many VF circuits and of FOX messages into many DC circuits. Terminating or bridging connections to individual circuits will be derived through reed relays which are controlled by the processor in response to instructions entered by console operators.

When switching matrices are used, it is recommended that none by employed at the primary patch bay, because the low frequency of line conditioning equipment substitution can be handled readily by manual patching. The circuit switching matrix should use the recently developed solid-state digital-crosspoint matrix (with pulse-width modulation) to effect a significant reduction in size. The DC switching matrix should use the same solid-state crosspoints, without the modulators and demodulators needed for VF circuits; this matrix should handle only low level DC signals. Reed relays are recommended for the group switching matrix because of the higher frequencies encountered and the relatively small size of the switching facility. The reed relays will be magnetically latched and will, therefore, need no power for holding. The solid-state matrices will require constant application of power to maintain established connection. It is assumed that an uninterrupted (no break) power source will be available to the ATEC facility. This feature, combined with multiple power supplies on a common DC voltage bus, will ensure continuity of holding power.

To obtain an operational evaluation of the effectiveness of automated switching in the ATEC environment, it is recommended that the DC switching matrix be implemented as a part of the Fuchu test bed. This matrix will be designed to provide switching access to all of the DC circuits appearing at the DC patch bay. It is recommended that varying fractions of the total DC circuits, starting with the most critical ones first and ranging upward to the full complement, be connected to the matrix to derive actual operational experience and, thus, provide a basis for determining the degree of matrix switching which should be provided in subsequent ATEC facilities.

7. DATA BASE

Both a static and a dynamic data base are needed. The static data base will provide detailed information on circuits, trunks, links, and equipment to include such items as identification, characteristics, configurations, and normal performance levels. It will also contain preplanned reroutes. Static data which are basically graphic in nature, such as circuit layouts, will be stored on slides in a static reference file projector at each operating console and will be available for random access call-up. The dynamic data base will contain information on the actual performance of circuits, trunks, links, and equipment. These data will be derived from status monitoring, fault isolation, quality control, equipment substitution, rerouting, and other actions taken inside and outside the ATEC facility

With exception of data in the slide file, all other static and dynamic data will be stored in a mass storage file (drum or disc) and will be available to operating personnel on a random access basis for console display. The mass storage file will need a minimum capacity of 250,000 characters for program and data storage, expandable in increments to at least one million characters

In addition, the capability is needed at the central control console for a high speed printout of any elements of the data base, particularly dynamic information such as a current summary of all Amber and Red alarm conditions.

8. REPORTING AND RECORD KEEPING

It is feasible to automate the preparation of reports to the DOCC and the O&M agency. The data processor will use stored report formats and will extract pertinent data from the data base. The partially completed report will be presented on a CRT display to the Central Controller for additions, deletions, modification, review, and editing. After release by the Central Controller, the processor can handle the report transmission over dedicated or common user transmission facilities.

It is recommended that a common report format be developed to satisfy the needs of the DOCC and all O&M agencies so as to reduce the volume of reporting and the associated work load on personnel.

From the contents of the data base, the processor can generate printout, either automatically by schedule or on operator requests, of the equivalents of most of the logs, forms, and records which are called for in Volume 2, Chapter 11, of DCAC 310-70-1, to reduce the work load of the technical controllers. Specifically, it is recommended that an activity log be generated at each console, recording all activities and events, with the log at the central control being the master station log. In addition, the processor will produce printouts of communications work orders on a teletypewriter in the Maintenance Section; maintenance personnel will be able to enter the results of their actions into the processor through the same teletypewriter. With regard to the other forms and records, it is recommended that the Government investigate the desirability of replacing present manual completion procedures by automated printouts of equivalents, i.e., the same information but not necessarily in exactly the same format.

One other form of recommended record keeping is the maintenance of journal on magnetic tape, recording all significant events for later retrieval and for analysis at a central off-line processing facility, such as at a DCCC or O&M element.

9. OPERATING CONSOLES

It is concluded that three different types of functional operating positions are needed: (a) Central Control, (b) Status Monitoring, and (c) Quality Control. Central Control is needed as a supervisory function and will maintain cognizance of the overall status of the facility and of the communications resources (i.e., perform system performance status monitoring), be responsible for the implementation of unplanned reroutes, and will complete and release reports. If the work load is large enough, the Central Controller should have an assistant to handle system performance matters.

The Status Monitoring operator will be responsible for link, equipment, and circuit monitoring, for fault isolation, for coordination with other DCS stations and with users, for equipment substitution, and preplanned circuit restorations and reroutes. In larger facilities, more than one operating position may be required.

The quality control operator will be required to perform detailed out-of-service testing of active and spare equipment, channels, and circuits in order to detect degradations before they become failures. He will perform acceptance testing of new and repaired equipment and circuits. He will assist the status monitoring operators by handling problems requiring lengthy fault isolation efforts, freeing these operators for other problems, and will temporarily assume the duties of a status monitoring operator in the event of unduly heavy problem load.

Each of the operating positions will be equipped with a universal interactive terminal containing a CRT display, an alphanumeric and function keyboard, a static reference file, and a teletypewriter. All consoles will [illegible] main voice intercom, and voice and teletypewriter orderwire capabilities. In addition, the Central Control

console will have a high speed line printer for high volume outputs; the status monitoring console will have analog and digital test equipment for fault isolation; and the quality control console will have test equipment suitable for detailed alignment and testing, as well as for fault isolation. The latter two consoles will be able to access any VF or DC circuit for monitoring or testing via monitor and test trunks in the patch bays; operator instructions to the processor will operate relays in the patch to effect the desired connections.

With exception of differences in test equipment complements, the remaining similarities among the various consoles permit temporary changes in console assignments to meet contingencies, such as console failures or peak loads.

10. DATA PROCESSING

A data processing subsystem is needed for the control of all automatic and semiautomatic functions, including:

- Scanner Control
- Monitoring Analysis
- Monitor and Test Trunk Control
- Switching Matrix Control
- Patch Cord Scanning
- Data Base Update
- CRT Display
- Printout
- Operator Input
- Reporting and Record Keeping

The subsystem requires a stored program small scale processor with core memory, a mass storage file (drum or disc) for program and data base storage, and a magnetic tape file for journal entry and retrieval. It is presently estimated that core memory will require as much as 32 thousand 16-bit words, the mass storage file a minimum of 250,000 characters, and the magnetic tape file-three tape drives (one for entry, one for retrieval, and one as a spare).

11. CONTROL COMMUNICATIONS

A voice intercommunications system is needed within the ATEC facility to enable coordination of activities at consoles, equipment bays, patch bays, and the maintenance section.

Voice and data orderwires conforming to the DCA policies expounded in DCAC-310-50-6 will satisfy the needs of the ATEC system for communications among DCS stations. Thus, ATEC facilities and other major nodal points will be tied together by express orderwires. Adjacent sites will communicate over link orderwires. Communications to remote radio sites and major users will also be needed. Where express orderwires do not permit direct connections between widely separated ATEC facilities, the common user AUTOVON network should be used.

Processor to processor communications between ATEC facilities on the same express orderwire will be provided by applying a speech-plus-teletype capability to the voice express orderwire. Similarly, monitoring information from, and control data to, remote radio sites and unmanned repeaters will be carried over voice orderwires in a speech-plus-teletype mode.

It is assumed that two way communication for operational direction by, coordination with, and reporting to DOCC elements will be enabled primarily by critical control circuits. When these are not available, common user networks (AUTOVON and AUTODIN) will be used. Maintenance management circuits will be used for communications with O&M agency elements when available, or else common user networks will be used.

When the ATEC facility serves an AUTOVON switch, results of interswitch trunk testing by the routiner should be sent over a DC circuit into the ATEC processor to report on trunks which have failed the routiner test. Similarly, when an AUTODIN switching center is served, the detection of excessive errors on an interswitch trunk or a user circuit passing through the ATEC facility should be reported to the ATEC processor over a DC circuit.

12. MONITORING OF REMOTE RADIO TERMINALS AND UNMANNED REPEATERS

The remote radio terminals of interest here are those HF receiver and transmitter sites and tropospheric scatter terminals which furnish long haul trunking for the ATEC facility but are physically separated from it by intersite links because of sitting requirements dictated by space considerations (HF antenna farms) or propagation needs. These remote sites are, in reality, merely an extension of the ATEC facility. As such, the monitoring of intersite and long-haul links and equipment is needed to complete the overall status picture. It is recommended that equipment monitoring of the types described in paragraph 3 be performed at these remote sites and that the measurements obtained be forwarded by speech-plus-teletype over the voice orderwire to the ATEC processor. Alarm conditions will be returned to the remote site and printed on a teletypewriter for the benefit of site personnel.

The status of an unmanned repeater, which is the operational and maintenance responsibility of the ATEC facility, must be known to facilitate fault isolation in a link which contains this repeater. It is recommended that monitoring of the type discussed in paragraph 3 for LOS/Tropo terminals be incorporated into the repeater and that the measured values be returned to the ATEC processor for analysis. A voice orderwire to the ATEC facility is needed for the benefit of maintenance personnel dispatched to the site to effect repairs; monitoring data can be transmitted using speech-plus-teletype.

The status of a satellite earth terminal is also of prime importance to the ATEC facility, in order to facilitate monitoring and fault isolation as well as to permit system optimization, as indicated in paragraph 3, the status information collected and processed at the satellite earth terminal should be summarized and relayed to the ATEC facility. Again, a voice orderwire is needed between the satellite earth terminal and the ATEC facility.

Error detection coding, by parity bits, will be used on all data transmissions to ensure the validity of the data received by the ATEC processor.

13. ATEC FACILITY

In the performance of a cost-effectiveness analysis, the activities of the ATEC facility were divided into six principal automated functions:

a. Circuit monitoring and fault isolation

b. Equipment/link monitoring

c. Quality control

d. Reporting

e. Switching

f. Remote site monitoring.

The processor subsystem, except for magnetic tapes, was assigned to circuit monitoring; the tapes were allocated to reporting. The patch bays were divided equally between circuit monitoring and quality control. Switching includes only the switching matrices. As a result of the analysis, it has been determined that the six functions rate as follows, in order of decreasing cost-effectiveness:

- Circuit monitoring and fault isolation

- Quality control

- Reporting
- Equipment/link monitoring
- Switching
- Remote site and unmanned repeater monitoring.

Further, cost-effectiveness was evaluated for three sizes of station:

- Small - less than 100 VF and 100 DC circuits
- Medium - 100 to 420 VF and 100 to 400 DC circuits
- Large - more than 420 VF and 400 DC circuits.

The results indicate that the implementation of ATEC in the small site is completely unjustifiable, but is worthwhile for the medium and large sites.

14. WORLDWIDE ATEC SYSTEM

A worldwide ATEC system is feasible and will be instrumental in improving and maintaining the performance of the DCS. The ATEC capability should be implemented only at the major nodal points of the DCS, constrained to the large and medium sites previously defined; it should also be installed at the remote radio sites and unmanned repeaters which are the direct responsibility of the ATEC facility.

The ATEC facility should be assigned for a geographic zone around it, encompassing all the manually operated stations, for which it maintains the general status of all the communications resources (i.e., system performance status monitoring), assists the other stations as needed, and reports for all stations in the zone.

ATEC facilities should cooperate in the resolution of problems which lie between them and should assist intervening manual stations to the maximum extent in such resolution. As already stated, primary communication between ATEC facilities should be by express orderwires, with the AUTOVON network as a supplement. In addition, ATEC facilities should be able to interchange status information of common interest by processor to processor channels.

15. ATEC IMPLEMENTATION

By way of illustration, three possible methods of implementation are presented. In the first, one site is implemented at a time with all functions.

In the second method, several stations are installed simultaneously but are initially equipped with only some of the ATEC functions. With time, other functions can be added in a modular fashion. A possible sequence for this method might be:

a. Circuit, equipment, and link monitoring; fault isolation; and reporting. This step would include the improved patch bays, consoles for status monitoring and Central Control, and the data processing subsystem, along with the equipment needed for monitoring and fault isolation.

b. Quality control

c. Switching (when justified)

d. Remote radio site and unmanned repeater monitoring.

Beyond the first step, it may be necessary to add additional core memory and program modules.

In the third method, a number of sites are installed simultaneously with all recommended functions but each function is limited to only a selected number of circuits, in particular, the most critical ones. As time proceeds, additional circuits are provided each function until the full capability is reached.

Of the three methods outlined, the second should permit the greatest number of sites to be equipped simultaneously for a given expenditure of funds, the first the smallest number. However, still other methods can be derived as a result of various combinations of the above defined methods and consistent with the Government's technical and funding requirements.

APPENDIX I

COST EFFECTIVENESS CALCULATIONS

The measurement of cost effectiveness requires that the savings attributable to the system being implemented be balanced against the cost of the system and show a savings after the payoff period.

The following paragraphs describe the derivation of the formulas for calculating the savings due to ATEC. In reviewing the methods of implementing ATEC at a DCS Station, two types of operator action seemed to lend themselves for use in categorizing failures at a station. The two types of operator action are: direct action or the action taken when the failure is directly within the area of responsibility of the tech control, and notify action or the action taken when the tech control becomes aware of a failure at a distant station.

An analysis of the failure reports from Fuchu Air Station yielded a distribution of failures by operator action as shown in Table I.

Table I Failure Distribution by Action

ACTION TYPE	DISTRIBUTION
Direct	7.9%
Notify	92.1%

From the analysis of the failure reports, a distribution of the types of failures and the average outage time for each type was obtained as shown in Table II.

Table II Failure Distribution by Type

FAILURE TYPE	DISTRIBUTION	AVERAGE OUTAGE TIME
Path	0.86%	30 min.
Nodes	87.10%	90 min.
User Terminal	9.35%	30 min.
Outside DCS	2.69%	165 min.

Combining Tables I and II yields a failure distribution that will be used in analyzing the savings. This failure distribution is shown in Table III.

Table III Failure Distribution by Type and Action

FAILURE CATEGORY		PATH	NODES	USER TERMINAL	OUTSIDE DCS
Average Outage Time in Minutes		30	90	30	185
Percentage Occurrence		0.86%	87.10%	9.35%	2.69%
Action Type					
Notify Action	0.921	0.79%	80.22%	8.61%	2.69%
Direct Action	0.079	0.07%	6.88%	0.74%	

The object of the subsequent calculations is to determine the savings for each function of the ATEC system. In order to keep the savings segregated, the availability of the functions will be used as an algebraic gathering point. Table IV is a list of the functions of the ATEC system and the availability.

Table IV ATEC Function Availability

FUNCTION	NAME	AVAILABILITY
1A	Output Circuit Monitoring	0.9991
1B	Input Circuit Diagnosis	0.9991
1C	Intra Node Diagnosis	0.9991
2	Equip/Link Monitoring	0.9992
3	Automated Patch	0.9993
4	Reporting	0.9989
5	Circuit Qualification and Testing	0.9992
6	Remote Site Equip/Link Monitoring	0.9991

For each failure category and action type in Table III, a savings expressed in time can be calculated. This time savings is in two categories, manpower and outage time. The manpower savings is accrued through the time savings resulting from the implementation of ATEC. The time savings occur because of the difference in time required to accomplish failure diagnosis and fault isolation, decisions on a restorative course of action and the accomplishment of those actions. The savings in outage time results from the ATEC monitoring system alerting the tech control of a failure and allowing corrective action to be taken before the user is aware that the failure has occurred. Since the majority of the failures are reported by the user in a manual tech control, there is a time savings between the report from the monitoring system in ATEC and the report from the user in the manual system. This outage time has been termed the indeterminate outage time and is different than the average outage time of a failure type. The difference is that presently one is reported and the other is not. This indeterminate outage time can be saved by ATEC as well as some, if not all, of the reported outage time. Table V is an estimate of the indeterminate outage time. A time estimate was made for each type of circuit and was an average of the estimates of the minimum and maximum response time. For DC circuits the minimum response time was estimated assuming the operator was attending the terminal device, and the maximum response time was estimated assuming the operator was attending to other duties.

Table V Estimate of Indeterminate Outage Time

CIRCUIT TYPE	TIME ESTIMATE MIN.	CIRCUIT DENSITY	PROBABILITY OF FAILURE OCCURRENCE
DC Circuits			
Clear Text (No Crypto)	30	1%	1%
Non-Traffic Flow Secure Crypto	30	14%	24%
Traffic Flow Secure Crypto	10	85%	75%
Average Indeterminate Outage Time DC = 11.0 Min.	--	--	--
VF Circuits			
Hot Line	30	10%	5%
Common User Manual Board	15	15%	15%
Common User Automatic Board	180	40%	15%
AUTOVON	5	20%	15%
VFCT Tone Channels	11	15%	50%
Average Indeterminate Outage Time VF = 63.7 Min.	--	--	--

For VF circuits the minimum response time was estimated assuming the voice circuit was in use and the maximum response time was estimated assuming the voice circuit was idle and some time would elapse before it was used or tested. An estimate was then made of the density of the circuit types and also of the probability that a failure would occur on that circuit type. From Table V, the average indeterminate outage time for DC circuits is 11.0 minutes. The average reaction time for the ATEC system on DC circuits is one-half of the monitor scan cycle time of two minutes. Therefore, the average indeterminate outage time savings for DC circuits is 10.0 minutes (11.0 - 1.0). Again, from Table V, the average indeterminate outage time for VF circuits is 63.7 minutes. The average reaction time for the ATEC system on VF circuits is one-half of the scan cycle time of one minute. Therefore, the average

Indeterminate outage time savings for VF circuits is 28.2 minutes (83.7 - 8.3).

Average Indeterminate Outage Time Savings

Formula 1 ADS = 16.9 DC + 28.2 VF

The direct action outage time savings that can be expected from ATEC would be a savings of the average outage time of the failure, less the time it took to react with the ATEC system, plus the savings in the average indeterminate outage time.

Formula 2 DAS = T - AA + AIOT

where DAS = direct action outage time savings

T = average outage time for failure type

AA = reaction time for ATEC system

AIOT = average indeterminate outage time (Formula 1)

There are two areas in Table III where direct action outage time savings can be obtained. They are radar node failures and user terminal failures.

A failure that occurs within the ATEC node can be detected by either or both function 1, "Fault Detection and Isolation", or function 2, "Equipment/Link Monitoring". It was estimated that function 1 would detect 50% of these failures and function 2 would detect the remaining 50%. The reaction of the ATEC system to a node failure would thus be detection of the fault 50% by function 1, 50% by function 2, one of three corrective actions, a quality test of the system by function 3, and finally a report made on the failure by function 4. The three corrective actions are alternate routing, equipment substitution or equipment repair which make use of function 5, "Automated Patching".

The calculations for direct action outage time savings for node failures follows.

DAS = T - AA + AIOT

T = 90 minutes (reference Table III)

AA + AIOT = 50% (FT 1) + 50% (FT 2) + (1 of 3 actions) + [illegible]

where FT = Function

AA = Minimum reaction time of ATEC system

[illegible] Actions

(1) Channel substitution performed [illegible]% of the time

(2) Equipment substitution performed [illegible]% of the time

(3) Equipment repair performed [illegible]% of the time

Action (1) - Channel substitution is composed of the following:

- Coordination with distant node (time in minutes)

  Minimum time = [illegible]
  Maximum time = [illegible]
  Average time = [illegible]

- Auto patch at ATEC and manual patch at distant node. Manual patch requires more time and therefore takes precedence.

  Minimum time = [illegible]
  Maximum time = [illegible]
  Average time = [illegible]

Total time action (1) = [illegible]

Action (2) - Equipment substitution is an average between FC [illegible] automated patching when it is available and manual when FC [illegible] is unavailable.

Average Manual Patching Time = [illegible]
ATEC FC [illegible] = [illegible]

[illegible]

Action (3) - Equipment repair is composed of the following:

- Availability of maintenance man (performing other duties)

  Minimum time = [illegible]
  Maximum time = [illegible]
  Average time = [illegible]

- Investigate equipment problems

  Minimum time = [illegible]
  Maximum time = [illegible]
  Average time = [illegible]

- Obtain spare module for repair

  Minimum time = [illegible]
  Maximum time = [illegible]
  Average time = [illegible]

- Install new module in equipment

  Minimum time = [illegible]
  Maximum time = 5
  Average time = [illegible]

- Equipment test

  Minimum time = [illegible]
  Maximum time = 4
  Average time = [illegible]

Accumulated average time = [illegible]

Calculation of the average of the [illegible] actions follows.

[illegible]

[illegible]

Inserting in calculation of [illegible]

[illegible]

Each function has a reaction time which is an average between the automated function when it is available and manual when it is unavailable.

Function 1 is composed of three sections:

FT1A is the output circuit monitoring subsystem and is capable of [illegible] some of the average indeterminate outage time.

[illegible]

FT1B is the input circuit diagnostic.

Reaction times — Manual = [illegible]; ATEC = [illegible]

Average = [illegible]

FT1C is the cross-node diagnostic

Reaction times — Manual = [illegible]; ATEC = [illegible]

Average = [illegible]

Function 2 - Equipment/Link Monitoring

It is capable of [illegible] some of the average [illegible] outage time

[illegible]

Function 3 - Automated Patching

It is the average of the 3 actions previously described.

Average = [illegible]

Function 4 reporting is not included in outage time average since the action takes place after restorative actions have been accomplished.

Function 5 - Circuit Qualification and Testing

Restoration time [illegible] Minimum [illegible]

[illegible]

Average = [illegible]

Inserting in [illegible]

[illegible]

[illegible]

[illegible]

the [illegible] portion of the above equals

[illegible]

[illegible]

the [illegible] portion equals

[illegible]

Inserting in the [illegible] formula [illegible]

[illegible]

The numerical value 90 - 15.79 = 74.21 is outage time savings that is indirectly attributable to an ATEC function. The savings due to the ATEC functions were measured assuming the action could take place immediately. However, there are periods of inactivity due to other duties, busy test equipment or coordination circuits, etc. It was assumed that the undefined savings of inactivity time could be distributed across the ATEC functions involved in the calculations in a ratio of the manual time it took to perform the function.

Function	Manual Time	Ratio	Distributed Time (74.21)	Original Savings	Distributed Savings
FT 1A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FT 1B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FT 1C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FT 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FT 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FT 5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Following is the formula with the undefined saving of inactivity time distributed.

Formula 2

DAS(Node) = [illegible]

The calculations for direct return outage time savings for user terminals follows

DAS = T - AA - ADTC

T = 30 minutes (reference Table III)

AA = FT1B - 2 of 3 minutes - FT1 [illegible]

A user terminal failure is detected by FT1A, followed by an automatic diagnosis to determine if the failure is internal or external to the ATEC by FT1B. FT1A detects the failure on the circuit leaving the facility. FT1B detects the fault on the input circuit from the user terminal. Both restoration actions require coordination with the user terminal. The two restoration actions are either equipment substitution or equipment repair. This is followed by a qualification test before the circuit is restored to service.

2 Actions

(1) Equipment substitution performed 90% of the time

(2) Equipment repair performed 10% of the time

Action (1) Equipment substitution

Manual patching = 1.3

Action (2) Equipment repair
(refer to Action (3) under DAS node failure)

Average time = 29.5

Coordination - refer to DAS node failure

Average time = 5.5

Calculation of the average of the two actions follows:

5.5 + 90% (1.[illegible]) + 10% (29.5)

9.62 average reaction time for 2 actions

Inserting in AA from above and average times for functions (see DAS nodes)

AA = [illegible] + 2.[illegible]A1B + [illegible] + 2.4 + [illegible]TAS

AA = 15.[illegible] + 2.[illegible]A1B + [illegible]TAS

Inserting in the full formula DAS = T - AA - AIND (T = 30)

DAS (user terminal) = 30 - 15.[illegible] - 2.[illegible]A1B - [illegible]TAS - (AIND) A1A

In a similar manner to node failures the numerical value 30-15.[illegible] = 14.[illegible] is distributed over the savings in accordance with the ratios of the manual time to perform the functions involved.

Function	Manual Time	Ratio	Distributed Time (14.[illegible])	Original Savings	Distributed Savings
FU1A	[illegible]	1	[illegible]	(AIND) A1A	(AIND) A1A
FU1B	3.1	1.[illegible]	[illegible]	[illegible] A1B	[illegible]A1B
FU1[illegible]	2.4	1.44	[illegible]	[illegible] TAS	[illegible]TAS

Following is the formula with the undefined saving of inactivity time distributed.

Formula 4

DAS (user terminal) = (ADND)A1A + 11.18A1B + 7.29A5

The notify action outage time savings that can be expected from ATEC would be a savings of the average indeterminate outage time, plus any savings or reduction in manpower that occurred during the failure.

Formula 5

NAS = ADD + FU1B - K (FU 3 - FU 5)

where NAS = notify action outage time savings

K = a constant equal to the amount of time ATEC is involved in patching and testing

derivation of constant K

The average length of a link is equal to 130 miles (reference final technical report RADC-TR-65-29). An analysis of the Pacific circuit records yielded an average circuit length of 1016 miles. A comparison of these two figures gives an average of eight links per circuit. This means that on the average there are nine nodes involved in an average circuit. Patching for channel substitution involves two nodes. Nine nodes taken two at a time yields 36 combinations for patching. One node can be involved with eight others. 90 percent of the time patching will be channel substitution versus equipment substitution. Note: Equipment substitution involves only one node which could not be the ATEC because the failure was in the notify action category.

$$K = \frac{8}{36} \times 0.9 = 0.20$$

outage time savings due to the involved functions

FU1B

Manual time = 3.4
ATEC time = $\underline{1.2}$

Savings = 2.2 A1B

FU 3

Manual time = 1.3
ATEC time = $\underline{[illegible]}$

Savings = 1.[illegible]A3

FU5

Manual time = 2.4
ATEC time = [illegible]
Savings = [illegible] AS

Inserting in formula 5

NAS = (ADND)A1A - [illegible] A1B - [illegible] - [illegible] AR

Formula 5

NAS = (ADND)A1A - [illegible] A1B - [illegible] - [illegible] AS

Following are the calculations of the total saving by failure category maintaining the functional separation.

Path Failures

There can be no outage time savings for path failures since they are not man made.

Notify Action [illegible] failure distribution from Table [illegible].

Manpower Savings (Path - Notify Action)

In the manual system when a failure is reported, a diagnostic action (FU3) takes place to determine if the failure is internal or external. In the case being discussed, the failure would be external resulting in coordination with the next node followed by the generation of a report (FU4).

ATEC will save all of the manpower for the diagnosis (FU3) since this ATEC function is fully automated. There will also be some saving in the reporting (FU4).

diagnosis:	Manual time FU3	= [illegible]
reporting:	Manual time FU4	= [illegible]
	ATEC time FU4	= [illegible]
	Savings FU4	= [illegible]

[illegible] A1B - [illegible] = [illegible] A1B - [illegible]

- Path - Notify - Manpower

Direct Action [illegible] failure distribution from Table [illegible].

Manpower Savings (Path - Direct Action)

In the manual system when a failure is reported, a diagnostic action (FT1.5) takes place to determine if the failure is internal or external. In the case being discussed, an attempted coordination with the next node would reveal the failure. This would be followed by an estimate of [illegible] reroutes (FT3) for the high priority circuits with testing for each (FT5). This would be followed by the generation of a report (FT4).

ATEC will determine this type of failure from the equipment link monitoring function (FT2), and will save manpower in the patching (FT3), testing (FT5), and reporting areas (FT4).

(diagnostic)	Manual Time FT1.5	= [illegible]	due to FT2
coordination for diagnostic	Manual Time (Note 1)	= [illegible]	at ATEC
(patching) x [illegible]	Manual Time FT3	= [illegible]	
	ATEC Time FT3	= [illegible]	
	Savings FT3	= [illegible] x [illegible] = [illegible]	
(testing) x [illegible]	Manual Time FT5	= [illegible]	
	ATEC Time FT5	= [illegible]	
	Savings FT5	= [illegible] x [illegible] = [illegible]	

Note 1 Refer to action [illegible] under DAS for node failures.

(reporting)	Manual Time FT4	= [illegible]
	ATEC Time FT4	= [illegible]
	Savings FT4	= [illegible]

[illegible] =

[illegible]

Path - Direct - Manpower

Node Failures

Weekly Action [illegible] failure distribution from Table [illegible]

Outage Savings Formula [illegible]

NAS = 80.22% [(ADND) A1A - 2.8A1B + 0.2A3 + 0.14A5]

$\boxed{0.80\ (ADND)\ A1A - 2.25A1B - 0.16A3 + 0.11A5}$

(Node - Notify - Outage)

Manpower Savings (Node - Notify Action)

In the manual system when a failure is reported a diagnostic action (FU1B) will take place to determine if the failure is internal or external. In the case being discussed the failure would be external resulting in coordination with the next node. Patching (FU3) and testing (FU5) would be involved in accordance with the constant K that was previously derived. A report (FU4) would also be generated.

ATEC will save all of the manpower for the diagnosis (FU1B) and part of the patching (FU3), testing (FU5) and reporting (FU4).

(diagnosis)	Manual Time FU1B	= 3.0
(patching) x K	Manual Time FU3	= 1.3
	ATEC Time FU3	= 0.3
	Savings FU3	= 1.0 x 0.2 = 0.2
(testing) x K	Manual Time FU5	= 2.4
	ATEC Time FU5	= 1.7
	Savings FU5	= 0.7 x 0.2 = 0.14
(reporting)	Manual Time FU4	= 1.2
	ATEC Time FU4	= 0.27
	Savings FU4	= 0.93

80.22% (3.0A1B + 0.2A3 + 0.93A4 - 0.14A5) =

$\boxed{2.41A1B - 0.16A3 + 0.75A4 + 0.11A5}$

(Node - Notify - Manpower)

Direct Action (6.88% failure distribution from Table III)

Outage Savings (formula 3)

$$DAS = 6.88\% \left[0.80\,(A1ND)A1A + 23.02A1B + 30.65A1C + 0.20(A1ND)A2 + 9.9A3 + 17.77A5 \right]$$

$$\boxed{0.06(A1ND)A1A + 1.58A1B + 2.11A1C + 0.01(A1ND)A2 + 0.68A3 + 1.22A5}$$

(Node - Direct - Outage)

Manpower Savings (Node - Direct Action)

In the manual system when a failure is reported a diagnostic action (FU1B) will take place to determine if the failure is internal or external. In the case being discussed the failure is internal and a further diagnostic (FU1C) would be required to isolate the failure. Patching (FU3), testing (FU5) and reporting (FU4) would also be involved with resolving the failure.

ATEC will save all of the manpower for both diagnostic functions (FU1B and FU1C) and some of the manpower for the patching (FU3), testing (FU5) and reporting (FU4).

(first diagnostic)	Manual Time FU1B	= 3.0
(second diagnostic)	Manual Time FU1C	= 4.5
(patching)	Manual Time FU3	= 1.3
	ATEC Time FU3	= 0.3
	Savings FU3	= 1.0
(testing)	Manual Time FU5	= 2.4
	ATEC Time FU5	= 1.7
	Savings FU5	= 0.7
(reporting)	Manual Time FU4	= 1.2
	ATEC Time FU4	= 0.27
	Savings FU4	= 0.93

$$6.88\% \,(3.0A1B + 4.5A1C + 1.0A3 + 0.93A4 + 0.7A5) =$$

$$\boxed{0.21A1B + 0.31A1C + 0.07A3 + 0.06A4 + 0.05A5}$$

(Node - Direct - Manpower)

User Terminal Failures

Notify Action (8.61% failure distribution from Table III)

Outage savings (formula 5)

$$NAS = 8.61\% \left[(AIND)\ A1A + 2.8A1B - 0.2A3 - 0.14A5 \right]$$

$$\boxed{0.08\ (AIND)\ A1A + 0.24A1B - 0.02A3 + 0.01A5}$$

(User Terminal-Notify-Outage)

Manpower Savings (User Terminal-Notify Action)

In the manual system when a failure is reported a diagnostic action (FU1B) will take place to determine if the failure is internal or external. In the case being discussed the failure is external resulting in coordination with the next node. Patching and testing would not be involved in this case. A report would be generated (FU4).

ATEC will save all of the manpower for the diagnostic (FU1B) and part of the reporting (FU4).

(diagnosis)	Manual time (FU1B)	= 3.0
(reporting)	Manual time FU4	= 1.2
	ATEC time FU4	= 0.27
	Saving FU4	= 0.93

$$8.61\%\ (3.0A1B + 0.93A4) = \boxed{0.26A1B + 0.08A4}$$

(User Terminal-Notify-Manpower)

Direct Action (0.74% failure distribution from Table III)

Outage Savings (formula 4)

$$DAS = 0.74\% \quad (AIND)A1A + 11.19A1B + 7.29A5$$

$$0.01\ (AIND)A1A + 0.08A1B + 0.05A5$$

(User Terminal-Direct-Outage)

Manpower Savings (User Terminal - Direct Action)

In the manual system when a failure is reported a diagnostic action (FU13) will take place to determine if the failure is internal or external. In the case being discussed, the failure is external and immediately identifies the user terminal as the source of the failure. The failure would then be reported (FU4).

ATEC can save all of the manpower for the diagnostic (FU13) and some of the manpower for the report (FU4).

(diagnostic)	Manual time FU13	= 2.0
(reporting)	Manual time FU4	= 1.2
	ATEC time FU4	= 0.2[illegible]
	Savings FU4	= [illegible]

$$0.[illegible]\ (2.[illegible] + 0.[illegible]) = \boxed{0.[illegible] + 0.[illegible]}$$

(User Terminal–Direct–Manpower)

Outside DCS Failures

Notify Action (0.[illegible] failure distribution from Table [illegible])

Outage Savings (formula 8)

$$[illegible] = 2.[illegible]\ ([illegible]) = 2.[illegible] + 0.[illegible] - 0.[illegible]$$

$$\boxed{0.[illegible]\ ([illegible] - 0.[illegible] + 0.[illegible] - 0.[illegible]}$$

(Outside DCS – Notify – Outage)

Manpower Savings (Outside DCS – Notify action)

In the manual system when a failure is reported, a diagnostic action (FU13) will take place to determine if the failure is internal or external. In the case being discussed, the failure would be external resulting in coordination with the next node. Patching (FU3) and testing (FU5) would be involved in accordance with the constant K that was previously derived. A report (FU4) would be generated.

ATEC will save all of the manpower for the diagnostic (FU13) and part of the patching (FU3), testing (FU5), and reporting (FU4).

(diagnosis)	Manual time	FUB	= [illegible]
(patching) etc.	Manual time	FUB	= [illegible]
	ATEC time	FUB	= [illegible]
	Savings	FUB	= [illegible]
(testing) etc.	Manual time	FUB	= [illegible]
	ATEC time	FUB	= [illegible]
	Savings	FUB	= [illegible]
(reporting)	Manual time	FU4	= [illegible]
	ATEC time	FU4	= [illegible]
	Saving	FU4	= [illegible]

[illegible]

$$\boxed{[illegible]}$$

Outside DCS - Notify - Equipment

When remote site monitoring is implemented, it is closely associated with the ATEC monitoring. This means there is interaction between the two monitoring subsystems insofar as savings are concerned. The main ATEC sees failures that occur at the remote site in the notify action category. Implementation of remote site monitoring brings these failures within the diagnose action category. The additional savings that can be obtained from remote site monitoring is the difference between the savings available from the two action categories.

RSS = DAS - NAS

where RSS = remote site savings

DAS = Y - AA - AEND (formula 1)

NAS = (AEND) A1A + [illegible] (formula 2)

for a remote site

DAS = Y - AA - AEND

Y = [illegible] (reference Table II for entry)

AA = [illegible] scan cycle time (ATEC) + time to make telemetry report + manual patching time + manual testing time

AA = [illegible]

DAS = [illegible] - AEND

RSS = (DAS - NAS) AF

RSS = [illegible] - AEND) AF - [(AEND) A1A + [illegible]] AF

RMS = [illegible] − ([illegible] − [illegible] − [illegible]) [illegible]

RMS = [illegible]

The savings available to the remote site monitoring system are node failures in the direct action category and are a savings in outage time only.

4. RMS failure distribution from Table III

RMS = [illegible] ([illegible])

$\boxed{\text{[illegible]}}$

(Node − Facility − Outage)

Function 5, "Circuit Qualification and Testing" will afford savings in manpower in performing the quality monitoring function in addition to the testing associated with failures. An analysis of quality control schedule in ECAC [illegible], Volume I yielded the following results:

Manual System

[illegible] minutes per year per DC circuit in testing plus [illegible] minutes per year test equipment set up time

[illegible] DC − [illegible]

[illegible] minutes per year per VF circuit in testing plus [illegible] minutes per year test equipment set up time

[illegible] VF − [illegible]

ATEC System

[illegible] DC − [illegible]

[illegible] VF − [illegible]

Savings

Manual	[illegible] DC − [illegible]
ATEC	[illegible] DC − [illegible]
Savings, year	[illegible] DC − [illegible]

[illegible]	[illegible]
[illegible]	[illegible]
Savings/year	[illegible]

Formula -

[illegible] note: this is savings in minutes per year

[illegible]

Function 5, "Circuit Qualification and Testing" will also result in a reduction of the failure rate. This reduction was estimated to be [illegible]%, however, in keeping with the conservative estimates so far used in the calculations, a reduction of [illegible]% will be used.

Savings have already been calculated for the failures that occur at a station. The additional savings is a reduction of the [illegible] time plus the outage time that could not be saved for the failures that will be eliminated.

The direct action savings will be the total outage time less the savings already calculated.

Total outage time	= T - [illegible]
Calculated savings	= DRS
[illegible] savings	= T - [illegible] - DRS

for [illegible]

T = [illegible]
DRS = [illegible]
DRS = [illegible]
T - [illegible] - DRS = [illegible]

for user terminals

T = [illegible]
DRS = [illegible]
DRS = [illegible]
T - [illegible] - DRS = [illegible]

NODE FAILURES

[illegible]

mileage savings

[illegible]

[illegible] mileage [illegible]

manpower savings

[illegible]

[illegible] manpower

[illegible]

mileage savings

[illegible]

[illegible] mileage [illegible]

manpower savings

[illegible]

[illegible] manpower

[illegible]
[illegible]

mileage savings

[illegible]

[illegible] mileage time

manpower savings

[illegible]

[illegible] manpower

[illegible] ([illegible])

outage savings

[illegible]

[illegible] outage time

manpower savings

[illegible]

[illegible] manpower

[illegible]

[illegible] ([illegible])

outage savings

[illegible]

[illegible] outage time

manpower savings

[illegible]

[illegible] manpower

Totals	outage time	= [illegible]
	manpower	= [illegible]

[illegible]% reduction in failures

Formula [illegible]	outage time savings	= [illegible]
Formula [illegible]	manpower savings	= [illegible]

Other Sources - Outage Time & Manpower

Table VI lists all of the savings that were calculated and gives a total of the outage time savings and manpower savings for each function. This savings is per failure and is given in minutes. It also includes a difference in DC circuits and VF circuits. As stated previously, to convert the savings per failure into a savings per day it will be necessary to multiply by the failure rate per day of 15% that was determined from the [illegible] failure reports. Following are the derivations of the costs per minute for DC circuits, VF circuits and manpower

Circuit Costs

An analysis of the recurring circuit cost in DCA Rule-of-Thumb Pricing Guide for Military C-E System yield $[illegible] per mile per month cost for a VF circuit and that a DC circuit was approximately 1/4 the cost of a VF circuit.

An analysis of the [illegible] circuit records yielded that an average circuit was [illegible] miles long.

$[illegible]/Mile month X [illegible] miles average length circuit ÷ 30 days/month

÷ 24 hours/day ÷ 60 minutes/hour = $[illegible]/minute for VF circuits

Manpower Costs

A review of the available documents yielded the DA [illegible] Life Cycle Cost Manual from the Navy which contained personnel cost information. Navy pay grade E5 was selected as the average level for a Tech Controller. However, the pay for level E4 was used since there have been military pay raises subsequent to the publication of the document.

E4 $[illegible]/year
$[illegible]/minutes

The calculations of manpower savings were based on direct labor and are similar to a time and motion study. Experience in industrial engineering has shown that the results of a time and motion study of a non-routine testing situation must be multiplied by a factor of 2 to 2.5 in order to equate the results with reality where man time is not 100% productive. The manpower calculations here will use a factor of 2 as a conservative estimate.

Following are the calculations of the dollar savings for each function using the totals from Table VI, the cost factors from above and the per day failure rate factor of 15%.

Table XI Savings By Function And Failure Category

FAILURE CATEGORY	ACTION TYPE	SAVINGS IN	FUNCTION [illegible]	FUNCTION [illegible]	FUNCTION [illegible]	FUNCTION [illegible]
[illegible]	[illegible]	MANPOWER		[illegible]		
	DIRECT	MANPOWER				[illegible]
[illegible]	[illegible]	OUTAGE TIME	[illegible]	[illegible]		
		MANPOWER		[illegible]		
	DIRECT	OUTAGE TIME	[illegible]	[illegible]	[illegible]	[illegible]
		MANPOWER		[illegible]	[illegible]	
USER TERMINAL	[illegible]	OUTAGE TIME	[illegible]	[illegible]		
		MANPOWER		[illegible]		
	DIRECT	OUTAGE TIME	[illegible]	[illegible]		
		MANPOWER		[illegible]		
[illegible]	[illegible]	OUTAGE TIME	[illegible]	[illegible]		
		MANPOWER		[illegible]		
[illegible] FROM OTHER SOURCES		MANPOWER				
TOTAL		OUTAGE TIME	[illegible]	[illegible]	[illegible]	[illegible]
		MANPOWER		[illegible]	[illegible]	[illegible]

...ion And Failure Category

[illegible]	FUNCTION [illegible]	FUNCTION [illegible]	FUNCTION [illegible]	FUNCTION [illegible]	FUNCTION [illegible]
			[illegible]		
	[illegible]	[illegible]		[illegible]	
		[illegible]		[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]		[illegible]	
[illegible]		[illegible]	[illegible]	[illegible]	
		[illegible]		[illegible]	
			[illegible]		
				[illegible]	
			[illegible]		
		[illegible]			
		[illegible]	[illegible]		
				[illegible]	
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

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Function 1

section 1A 0.99 (AIND) A1A from Table VI

AIND = 10.0 DC + 63.2 VF (formula 1)

A1A = 0.9991 from Table IV

0.99 (10.0 DC + 63.2 VF) 0.9991

DC circuits

0.99 X 10.0 X 0.9991 X 25% X \$0.14 ÷ 6 =

\$0.06 DC per day or
\$21.06 DC per year

VF circuits

0.99 X 63.2 X 0.9991 X 25% X \$0.14 =

\$2.19 VF per day or
\$798.58 VF per year

total savings section 1A

\$21.06 DC per year
\$798.58 VF per year

section 1B

outage savings 4.23 A1B from Table VI
A1B = 0.9991 from Table IV
4.23 X 0.9991

DC circuits

4.23 X 0.9991 X 25% X \$0.14 ÷ 6 =

\$0.02 DC per day or
\$9.02 DC per year

VF circuits

4.23 X 0.9991 X 25% X $0.14 =

$0.15 VF per day or
$53.98 VF per year

manpower savings 3.01A1B from Table VI
A1B = 0.9991 from Table IV
3.01 X 0.9991

VF + DC circuits

3.01 X 0.9991 X 25% X $0.13 =

$0.10 (VF + DC) per day or
$35.66 (VF + DC) per year x 2 =

$71.32 (VF + DC) per year

total savings section 1B

$9.02 DC + $71.32 DC = $80.34 DC per year

$53.98 VF + $71.32 VF = $125.30 VF per year

section 1C

outage savings 2.11 A1C from Table VI
A1C = 0.9991 from Table IV
2.11 x 0.9991

DC circuits

2.11 X 0.9991 X 25% X $0.14 ÷ 6 =

$0.01 DC per day or
$4.49 DC per year

VF circuits

2.11 X 0.9991 X 25% X $0.14 =

$0.07 VF per day or
$26.94 VF per year

manpower savings 0.31 A1C from Table VI
A1C = 0.9991 from Table IV
0.31 X 0.9991

VF + DC circuits

0.31 X 0.9991 X 25% X $0.13 =

$0.01 (VF + DC) per day or
$3.69 (VF + DC) per year x 2 =

$7.38 (VF + DC) per year

total savings section 1C

$4.49 DC + $7.38 DC = $11.87 DC per year

$26.94 VF + $7.38 VF = $34.32 VF per year

Total savings Function 1

$21.06 DC + $80.34 DC + $11.87 DC = $113.27 DC per year

$798.58 VF + $125.30 VF + $34.32 VF = $958.20 VF per year

Function 2

outage savings 0.01 (AIND) A2 from Table VI
A2 = 0.9992 from Table IV
AIND = 10.0 DC + 63.2 VF (formula 1)
0.01 (10.0 DC + 63.2 VF) 0.9992

DC circuits

0.01 X 10.0 X 0.9992 X 25% X $0.14 ÷ 6 =

$0.0006 DC per day or
$0.22 DC per year

VF circuits

0.01 X 63.2 X 0.9992 X 25% X $0.14 =

$0.02 VF per day or
$8.07 VF per year

manpower savings 0.01 A2 from Table VI
A2 = 0.9992 from Table IV
0.01 X 0.9992

VF + DC circuits

0.01 X 0.9992 X 25% X $0.13 =

$0.0003 (VF + DC) per day or
$0.11 (VF + DC) per year X 2 =

$0.22 (VF + DC) per year

Total savings Function 2

$0.22 DC + $0.22 DC = $0.44 DC per year

$8.07 VF + $0.22 VF = $8.29 VF per year

manpower savings = $0.22 per circuit per year

Function 3

outage savings 0.87 A3 from Table VI
A3 = 0.9993 from Table IV
0.87 X 0.9993

DC circuits

0.87 X 0.9993 X 25% X $0.14 ÷ 6 =

$0.01 DC per day or
$1.86 DC per year

VF circuits

0.87 X 0.9993 X 25% X $0.14 =

$0.03 VF per day or
$11.10 VF per year

manpower savings   0.25 A3 from Table VI
A3 = 0.9993 from Table IV
0.25 X 0.9993

VF + DC circuits

0.25 X 0.9993 X 25% X $0.13 =

$0.01 (VF + DC) per day or
$2.96 (VF + DC) per year or X 2 =

$5.92 (VF + DC) per year

Total savings Function 3

$1.86 DC + $5.92 DC $7.78 DC per year

$11.10 VF + $5.92 VF = $17.02 VF per year

Function 4

manpower savings   0.88 A4 from Table VI
A4 = 0.9989 from Table IV
0.88 X 0.9989

VF + DC circuits

0.88 X 0.9989 X 25% X $0.13 =

$0.03 (VF + DC) per day or
$10.44 (VF + DC) per year x 2 =

$20.88 (VF + DC) per year

Total savings Function 4

$[illegible] DC per year

$[illegible] VF per year

manpower savings = $[illegible] per circuit per year

Function 5

outage savings 1.39A5 from Table VI
A5 = 0.9992 from Table IV
1.38 X 0.9992

DC circuits

1.39 X 0.9992 X 25% X $0.14 ÷ 8 =

$0.01 DC per day or
$2.85 DC per year

VF circuits

1.39 X 0.9992 X 25% X $0.14 =

$0.05 VF per day or
$17.74 VF per year

manpower savings 0.17 A5 from Table VI
A5 = 0.9992 from Table IV
0.17 X 0.9992

VF + DC circuits

0.17 X 0.9992 X 25% X $0.13 =

$0.01 (VF + DC) per day or
$2.01 (VF + DC) per year x 2 =

$4.02 (VF + DC) per year

special savings in manpower

4.07 DC + 58.28 VF + 478.90 (formula 7)

DC circuits

4.07 X $0.13 = $0.53 DC per year X 2 = $1.06 DC per year

VF circuits

58.28 X $0.13 = $[illegible] VF per year X 2 = $[illegible] VF per year

general savings

478.90 X $0.13 = $[illegible] general per year X 2 = $[illegible] general per year

additional special savings in outage time and man power

outage savings (formula 8)

19.39 A5
A5 = 0.9992
19.39 X 0.9992

DC circuits

19.39 X 0.9992 X 25% X $0.14 ÷ 6 =

$0.11 DC per day or
$41.25 DC per year

VF circuits

19.39 X 0.9992 X 25% X $0.14 =

$0.69 VF per day or
$247.51 VF per year

manpower savings (formula 9)

1.15 A5
A5 = 0.9992
1.15 X 0.9992

VF + DC circuits

1.25 X [illegible] X 25% X $[illegible] =

$[illegible] (VF + DC) per day or
$[illegible] (VF + DC) per year X 2 =
$[illegible] (VF + DC) per year

Total savings Function 5

$[illegible] DC + $[illegible] DC + $[illegible] DC + $[illegible] DC + $[illegible] DC =

$[illegible] DC per year

$[illegible] VF + $[illegible] VF + $[illegible] VF + $[illegible] VF + $[illegible] VF =

$[illegible] VF per year

$[illegible] general = $[illegible] general per year

manpower savings = $[illegible] per circuit per year

+ $[illegible] per DC circuit per year + $[illegible] per VF circuit

per year + $[illegible] general per year

Function 6

outage savings 5.69A5 from Table VI
A5 = 0.9991 from Table IV
5.69 X 0.9991

DC circuits

5.69 X 0.9991 X 25% X $0.14 ÷ 6 =

$0.03 DC per day or
$12.12 DC per year

VF circuits

5.69 X 0.9991 X 25% X $0.14 =

$0.20 VF per day or
$72.64 VF per year

Total savings Function 6

$12.12 DC per year

$72.64 VF per year

Table VII lists the dollar savings per year for each function on a per circuit basis. This permits the calculation of the savings for any site given the quantity of DC and VF circuits.

TABLE VII SAVINGS/YEAR/FUNCTION/CIRCUIT

FUNCTION	CIRCUIT TYPE		GENERAL
	DC	VF	SAVINGS
1	$1[illegible].77	$662.10	
2	$ 0.44	$ [illegible]	
3	$ 3.78	$ 17.02	
4	$ 20.35	$ 29.66	
5	$ 76.51	$330.73	$124.78
6	$ 12.12	$ 72.64	

The manpower savings are as follows:

$138.02 DC per year
$161.20 VF per year
$124.78 general per year

Three model sites were established in order to continue the analysis into the area of station size. An analysis was made of 72 stations for which a VF circuit count could be obtained. Sixty-seven of these stations also listed a DC circuit count. The information in Table VIII is the results of the analysis.

TABLE VIII STATION SIZE VS CIRCUIT QUANTITIES

STATION SIZE	CIRCUIT QUANTITY DC	CIRCUIT QUANTITY VF	DENSITY OF STATION TYPE
SMALL	20	40	35%
MEDIUM	150	220	55%
LARGE	350	500	10%

This information was then expanded into the three model sites by making assumptions relative to the number of links and types of equipment. Following are the three sites listing the assumptions that were made.

Small AYDC

40 VF channels (FDM) - 20 DC channels (TDM)

assume: 2 links - microwave

24 channels each link, each with 4 spare channels

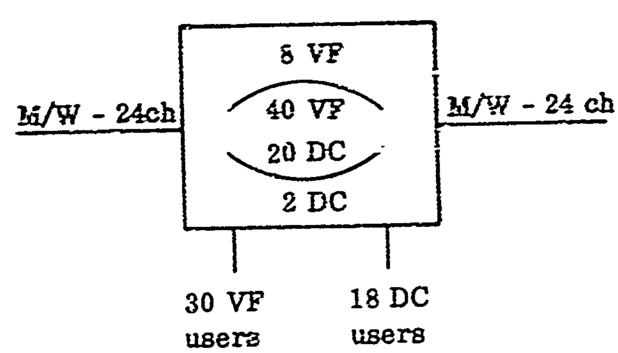
2 - 16 channel VFCT (FSK)

5 spare channels each unit

30 VF users - 8 VF normal through

18 DC users - 2 DC normal through

no remote facilities



Medium ATEC

280 VF channels (DCS) - 160 DC channels (DCS)

assume: 1 link - microwave   180 channels

1 link - tropo   60 channels

2 links - microwave to HF TX & RX remote sites,

24 channels each

6 HF radio circuits 4 channels each, 4 spare channels, one

each on 4 circuits

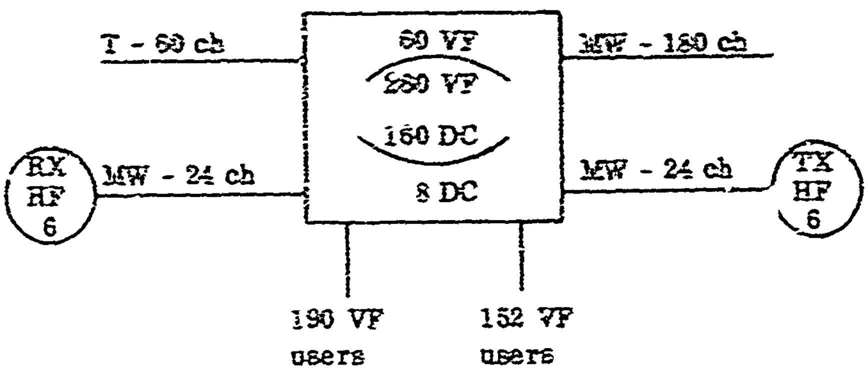
16 - 16 channel VFCT (FSK)

190 VF users - 90 VF normal through

152 DC users - 8 DC normal through

HF transmitter site   6 HF transmitters

HF receiver site   6 HF receivers



Large ATDC

580 VF channels ([illegible]) - 548 DC channels ([illegible])

assume: 3 links - microwave 1 - 60, 1 - 120, 1 - 180 channels

1 link - tropo 120 channels

4 links - cable carrier, each 12 channels

2 links - microwave to HF TX & RX remote sites 36 channels

each - 4 spare channels each

8 HF radio circuits, 4 channels each

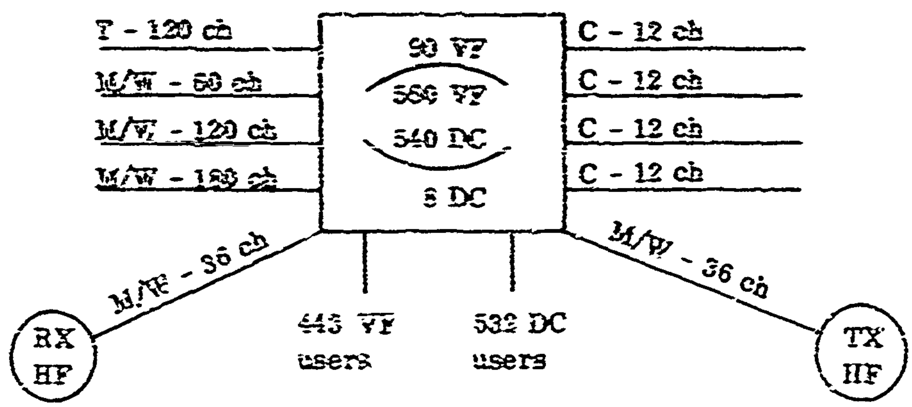
12 - 16 channel VFCT (FSK)

15 - 16 channel VFCT (FSK)

12 spare DC channels

443 VF users - 90 VF normal through

532 DC users - 16 DC normal through



Using the VF and DC circuit quantities for each size model site and Table VII, the savings per year per function were calculated and are listed in Table IX.

TABLE IX SAVINGS/YEAR/FUNCTION

FUNCTION	SMALL	MEDIUM	LARGE
1	$40,593	$267,255	$597,758
2	$ 340	$ 2,226	$ 4,880
3	$ 836	$ 5,670	$ 13,732
4	$ 1,253	$ 8,770	$ 22,968
5	$14,359	$ 95,631	$220,924
6	---	$ 2,380	$ 3,093
SYSTEM	$57,381	$381,932	$863,355

Some of the ATEC equipments will be newly developed items and will have the one time development costs associated with them. In order to spread these one time costs, a total of 50 ATEC installations was assumed. This 50 was then divided into 8 large, 25 medium and 17 small sites in accordance with the density distribution shown in table VIII. The equipment costs for one small, medium and large site were developed. A summary of these costs are shown in Tables X through XII.

The savings and costs for each function are compared in Table XIII. The pay-off period in years was calculated by dividing the cost by the savings to arrive at the multiplying factor. A 10% discount rate was used to equate tomorrow's dollars with today's dollars, and is tabulated in Table XIV. To establish the pay-off period the multiplying factor is compared with the "accumulated sum of the discount factor" until the closest value of the sum which is equal to or less than the multiplying factor is located. This establishes the integer value of the pay-off period in years. The decimal value is established by estimating the decimal multiple of the "discount factor" in the next higher year.

An examination of Table XIII shows that a small site is not cost effective. A medium and large site requires further examination. Following are cost

Table X Small Site Costs By Function

EQUIPMENT COST ESTIMATE SMALL SITE				
FUNCTION	BASIC EQUIPMENT COST	SYSTEMS ENGINEERING, INSTALLATION, ETC. COSTS 100% BASIC EQUIP. COST	SPARE PARTS 25% BASIC EQUIPMENT COST	TOTAL
1. OUTPUT CIRCUIT MONITORING AND FAULT ISOLATION	$145,295	$145,295	$36,324 TEST EQUIP $34,659	$361,573
2. EQUIP/LINK MONITORING	$12,284	$12,284	$3,071	$27,639
3. AUTOMATED PATCH	$104,810	$104,810	$26,203	$235,823
4. REPORTING	$18,000	$18,000	$6,500	$42,500
5. CIRCUIT QUALIFICATION AND TESTING	$136,025	$136,025	$34,006	$306,056
6. REMOTE SITE EQUIP/LINK MONITORING	-	-	-	-
TOTAL SYSTEM COST	$416,414	$416,414	$140,763	$973,591

Table XI Medium Site Costs By Function

EQUIPMENT COST ESTIMATE MEDIUM SITE				
FUNCTION	BASIC EQUIPMENT COST	SYSTEMS ENGINEERING, INSTALLATION, ETC. COSTS 100% BASIC EQUIP. COST	SPARE PARTS 25% BASIC EQUIPMENT COST	TOTAL
1. OUTPUT CIRCUIT MONITORING AND FAULT ISOLATION	$236,995	$236,995	$59,998 TEST EQUIP. $34,734	$568,723
2. EQUIP/LINE MONITORING	$24,888	$24,888	$6,222	$55,998
3. AUTOMATED PATCH	$239,000	$239,000	$59,750	$537,750
4. REPORTING	$18,000	$18,000	$6,500	$42,500
5. CIRCUIT QUALIFICATION AND TESTING	$194,025	$194,025	$48,506	$436,556
6. REMOTE SITE EQUIP LINE MONITORING	(3 LOCATIONS) $22,148	$22,148	$11,074 TEST EQUIP. $69,828	$125,198
TOTAL SYSTEM COST	$735,056	$735,056	$296,613	$1,766,725

Table XII Large Site Costs By Function

EQUIPMENT COST ESTIMATE LARGE SITE				
FUNCTION	BASIC EQUIPMENT COST	SYSTEMS ENGINEERING, INSTALLATION, ETC. COSTS 100% BASIC EQUIP. COST	SPARE PARTS 25% BASIC EQUIPMENT COST	TOTAL
1. OUTPUT CIRCUIT MONITORING AND FAULT ISOLATION	$399,206	$399,206	$99,802 TEST EQUIP. $34,809	$933,023
2. EQUIP/LINK MONITORING	$39,472	$39,472	$9,868	$88,812
3. AUTOMATED PATCH	$591,500	$591,500	$147,875	$1,330,875
4. REPORTING	$27,000	$27,000	$6,750	$60,750
5. CIRCUIT QUALIFICATION AND TESTING	$255,025	$255,025	$63,756	$573,806
6. REMOTE SITE EQUIP/LINK MONITORING	(2 LOCATIONS) $30,425	$30,425	$15,226 TEST EQUIP. $69,252	$145.358
TOTAL SYSTEM COST	$1,342,628	$1,342,828	$447,368	$3,132,824

Table XIII Cost Comparison - DCS 97 8% Efficient

STATION		FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5	FUNCTION 6	TOTAL SYSTEM
SMALL 60 Channels 20 DC Circuits 40 VF Circuits	Savings	$40,583	$340	$636	$1,253	$14,359	-	$57,361
	Cost	$361,573	$27,639	$235,823	$42,300	$300,056	--	$973,591
	Pay-Off Period	17.4 Y	∞	∞	∞	∞	-	∞
MEDIUM 420 Channels 160 DC Circuits 260 VF Circuits	Savings	$267,255	$2,226	$5,670	$8,770	$85,631	$2,380	381,832
	Cost	$566,723	$55,998	$537,750	$42,500	$436,556	$125,198	$1,768,725
	Pay-Off Period	2.3 Y	∞	∞	6.1 Y	5.6 Y	∞	5.7 Y
LARGE 1100 Channels 540 DC Circuits 560 VF Circuits	Savings	597,758	$4,880	$13,732	$22,968	$220,924	$3,093	$863,355
	Cost	$933,023	$88,812	$1,330,875	$60,750	$573,806	$145,358	$3,132,624
	Pay-Off Period	1.6 Y	∞	∞	2.9 Y	2.8 Y	∞	4.2 Y

Table XIV Discount Factor

YEARS	DISCOUNT FACTOR	ACCUMULATED SUM OF DISCOUNT FACTOR
1	1.000	1.000
2	0.909	1.909
3	0.826	2.735
4	0.751	3.486
5	0.683	4.169
6	0.621	4.790
7	0.565	5.355
8	0.514	5.869
9	0.467	6.336
10	0.425	6.761
11	0.386	7.147
12	0.351	7.498
13	0.319	7.817
14	0.290	8.107
15	0.264	8.371
16	0.240	8.611
17	0.218	8.829
18	0.198	9.027
19	0.180	9.207
20	0.164	9.371

effective calculations for the implementation of various combination of functions for a medium and large site.

The average overall outage time taking into consideration the failure distribution is 86 minutes. Assuming an equal distribution of VF and DC circuits, the average indeterminate outage time is 37 minutes. This gives an average total outage time of 123 minutes per failure per day. Following is the calculation of the efficiency of the DCS using a 25% failure rate.

$$100\% - \frac{25\% \times 123}{1440 \text{ (minutes per day)}} = 97.86\%$$

The results of the "Scope Creek" testing indicated that the DCS is not operating at this high an efficiency. Table XV shows the ATEC cost effectiveness for the DCS at 95% efficiency. Table XVI shows the ATEC cost effectiveness for the DCS at 90% efficiency.

Table XVII shows the ATEC cost effectiveness for the DCS at 85% efficiency. Table XVIII shows the ATEC cost effectiveness for the DCS at 80% efficiency.

The general formula used to calculate manpower requirements is 4.2 times the number of men for a shift. Following is the calculations for the reduction in manpower of the three model sites.

SMALL	20 DC ckts x $138.02	= $2760.40
	40 VF ckts x $161.20	= $6448.00
	general	$ 124.78
	Total	= $9333.18
	dividing by $15,950 per man	= 0.59 men per day
	dividing by 3 shifts per day	= 0.20 men per shift
	multiplying by 4.2	= 1 man
MEDIUM	160 DC ckts x $138.02	= $22,083.20
	260 VF ckts x $161.20	= $41,912.00
	general	$ 124.78
	Total	= $64,119.98
	dividing by $15,950 per man	= 4 men per day
	dividing by 3 shifts per day	= 1.34 men per shift
	multiplying by 4.2	= 6 men
LARGE	540 DC ckts x $138.02	= $ 74,530.80
	560 VF ckts x $161.20	= $ 90,272.00
	general	$ 124.78
	Total	= $164,927.58

Table XV Cost Comparisons - DCS 95% Efficient

STATION		FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5	FUNCTION 6	TOTAL SYSTEM
SMALL 60 Channels 20 DC Circuits 40 VF Circuits No Remote Sites	Savings	$94,825	$794	$1,953	$2,927	$33,543	-	$134,042
	Cost	$361,573	$27,639	$235,823	$42,500	$306,556	-	$973,591
	Pay-Off Period	4.5 Y	∞	∞	∞	19.5 Y	-	11.3Y
MEDIUM 420 Channels 160 DC Circuits 260 VF Circuits 2 Remote Sites 24 Channels Ea.	Savings	$824,308	$5,200	$13,245	$20,487	$223,384	$5,560	$892,192
	Cost	$568,723	$55,998	$537,750	$42,500	$436,556	$125,198	$1,788,725
	Pay-Off Period	0.90 Y	40 Y	∞	2.2 Y	2.1 Y	∞	2.2 Y
LARGE 1100 Channels 540 DC Circuits 560 VF Circuits 2 Remote Sites 35 Channels Ea.	Savings	$1,368,363	$11,400	$32,978	$53,653	$516,878	$7,225	$2,016,797
	Cost	$933,023	$88,812	$1,330,875	$60,750	$573,808	$145,358	$3,132,624
	Pay-Off Period	0.67 Y	12.9Y	∞	1.1 Y	1.2 Y	∞	1.6 Y

Table XVI Cost Comparisons - OCS 90% Efficient

STATION		FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5	FUNCTION 6	TOTAL SYSTEM
SMALL 60 Channels 28 DC Circuits 40 VF Circuits No Remote Sites	Savings	$189,850	$1,588	$3,908	$5,854	$87,085	-	$288,084
	Cost	$381,573	$27,839	$235,823	$42,500	$306,056	-	$873,591
	Pay-Off Period	2.0 Y	∞	∞	11.3Y	5.5Y	-	4.2Y
MEDIUM 420 Channels 160 DC Circuits 280 VF Circuits 2 Remote Sites 24 Channels Ea.	Savings	$1,248,615	$10,400	$26,490	$40,893	$446,788	$11,119	$1,784,305
	Cost	$568,723	$55,998	$537,750	$42,500	$436,556	$125,198	$1,766,725
	Pay-Off Period	0.48Y	7.1Y	∞	2.1Y	0.98Y	∞	1.1Y
LARGE 1100 Channels 540 DC Circuits 560 VF Circuits 2 Remote Sites 38 Channels Ea.	Savings	$2,782,725	$22,798	$64,156	$107,306	$1,032,157	$14,450	$4,033,593
	Cost	$933,023	$98,812	$1,330,875	$60,750	$573,806	$145,358	$3,132,624
	Pay-Off Period	0.33Y	4.6Y	∞	0.57Y	0.56Y	25.8Y	0.78Y

Table XVII Cost Comparisons - DCS 85% Efficient

STATION		FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5	FUNCTION 6	TOTAL SYSTEM
SMALL 80 Channels 20 DC Circuits 40 VF Circuits No Remote Sites	Savings	$284,478	2,383	5,659	8,781	108,828	-	402,127
	Cost	$361,573	$27,639	$235,823	$42,500	$308,056	--	$973,581
	Pay-Off Period	1.3 Y	∞	∞	8.1 Y	3.4 Y	-	2.8 Y
MEDIUM 420 Channels 160 DC Circuits 260 VF Circuits 2 Remote Sites 24 Channels Ea.	Savings	1,872,923	15,800	39,735	91,460	670,182	16,879	2,676,579
	Cost	$588,723	$55,998	$537,750	$42,500	$436,556	$125,198	$1,766,725
	Pay-Off Period	0.30 Y	4.1 Y	∞	0.69 Y	0.65 Y	12.1 Y	0.66 Y
LARGE 1100 Channels 540 DC Circuits 560 VF Circuits 2 Remote Sites 36 Channels Ea.	Savings	4,169,088	34,199	96,234	160,980	1,548,235	21,676	6,050,392
	Cost	$933,023	$88,812	$1,330,875	$60,750	$573,806	$145,358	$3,132,624
	Pay-Off Period	0.22 Y	2.6 Y	∞	0.38 Y	0.37 Y	6.9 Y	0.52 Y

Table XVIII Cost Comparisons - DCS 80% Efficient

STATION		FUNCTION 1	FUNCTION 2	FUNCTION 3	FUNCTION 4	FUNCTION 5	FUNCTION 6	TOTAL SYSTEM
SMALL 80 Channels 20 DC Circuits 40 VF Circuits No Remote Sites	Savings	379,301	3,177	7,812	11,708	134,170	-	536,168
	Cost	$381,573	$27,639	$235,823	$42,500	$306,056	--	$973,591
	Pay-Off Period	0.95 Y	16.4 Y	∞	4.2 Y	2.4 Y	-	1.8 Y
MEDIUM 420 Channels 150 DC Circuits 280 VF Circuits 2 Remote Sites 24 Channels Ea.	Savings	2,497,231	20,808	52,980	81,947	893,576	22,238	3,368,773
	Cost	$568,723	$55,998	$537,750	$42,500	$436,556	$125,198	$1,788,725
	Pay-Off Period	0.23 Y	2.8 Y	26.8 Y	0.52 Y	0.49 Y	7.5 Y	0.50 Y
LARGE 1100 Channels 540 DC Circuits 560 VF Circuits 2 Remote Sites 36 Channels Ea.	Savings	5,565,451	45,800 Y	128,312	214,613	2,064,314	28,901	8,067,[illegible]
	Cost	$933,023	$88,812	$1,330,875	$80,750	$573,806	$145,358	$3,132,624
	Pay-Off Period	0.17 Y	2.1 Y	30.1 Y	0.28 Y	0.28 Y	6.4 Y	0.38 Y

dividing by $15,950 per man	= 10.34 men per day
dividing by 3 shifts	= 3.45 men per shift
multiplying by 4.2	= 14 men

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13. ABSTRACT

This report describes a study performed to determine the most cost-effective and technically effective means and methods of automatizing the functions of DCS technical control facilities. In determining the degree of automation that could be applied to the various functions, the DCS environment, telecommunications systems and equipment, and technical control operating activities were considered. The requirements for Automated Tech Control (ATEC) facilities and an ATEC-augmented DCS were also determined.

As a result of this study, it was concluded that circuit status monitoring provides the most benefit in fault detection and localization. Automation of this and other ATEC functions is recommended through use of a processor, which would also provide controlled data storage and display information to manned consoles. In addition, the processor would correlate status monitoring information from equipment, links, and circuits to provide performance assessment and trend analysis for indications of "green-amber-red" states. Other recommended functions to be automated include: report generation; remote site status monitoring; and group patch, circuit patch and digital patch switching. The cost of switch matrices precludes implementation of all circuits and switching is therefore recommended only on a limited basis, such as for high priority digital and audio circuits, and selected carrier multiplex groups.

The recommended ATEC configuration provides for Status Monitoring, Quality Control and Central Control consoles to be operated by tech control personnel. (over)

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Automation						
Analysis						
Military Communications						
Telecommunications						
Performance Assessment						
Link Status Monitoring						
Equipment Status Monitoring						
Circuit Status Monitoring						
Systems Status Monitoring						
Central Control						
Telemetry						
Automated Patching						
Reporting Requirements						
Programming						
Processor						
Display and Control						
Orderwire						
Line Conditioning						
Central Station Clock						
Testing						
Cost Effeftiveness						
Reliability						
Standardization						
Modularization						
Military Requirements						

Abstract (continued)

Patch bays with sealed normal-through contacts are recommended with connection capability to test and monitor buses which will be accessed by the console operators. An integrated orderwire and intercom capability is recommended for coordination and control between elements of the ATEC facility; with other ATEC and manual technical control facilities; and with subordinate patch and test facilities, users and communications suppliers.